EDITORIAL

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IOTN Issue 17 (January 2013) includes reports on sea turtle biology and conservation from all reaches of the Indian Ocean, with a breadth of topics that include community initiatives and conservation programmes, sea turtle interactions with fisheries, strandings, hatcheries, nesting reports, project profiles, and photographic identification of individual turtles. The IOTN Research Summaries return in 2013, as Jeff Seminoff updates us on new technology, including solar tags and miniature satellite transmitters, stable isotope tracking and skeleto-chronology, used to determine turtle movement at sea.

Our opening report examines the activities of sea turtle hatcheries in Sri Lanka, and their potential contribution to sea turtle conservation. *In situ* incubation of sea turtle nests is the most desirable scenario for most nesting beaches, but eggs in the Indian Ocean and South East Asia are often collected for incubation in a hatchery to reduce natural and human threats to nests, including poaching, predation, and beach erosion. While a number of hatcheries in the region are maintained by governmental and non-governmental agencies for protection and/or education and outreach, some also provide income to local communities through ecotourism. However, the industry is often unregulated and hatchery management practices (including those by government and NGOs) fail to consider the environmental and natural biology of hatchlings.

IOTN would be interested in publishing similar studies from other countries in this region and recommends a wider conversation with regional hatchery managers, NGOs and enforcement agencies to ensure responsible collection and incubation of eggs, immediate release of the majority of hatchlings, and accurate record keeping and reporting.■

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ARTICLES

SEA TURTLE HATCHERIES IN SRI LANKA: THEIR ACTIVITIES AND POTENTIAL CONTRIBUTION TO SEA TURTLE CONSERVATION

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ABSTRACT

Hatcheries can be used as an *ex situ* conservation tool, however their contribution to the effective management of sea turtles is highly debated. A questionnaire survey was used to assess the activities of the seven hatcheries currently in operation in Sri Lanka. All the hatcheries were operated by private owners, and the primary motive was profit from ecotourism. During the 1990's, hatcheries only operated during the tourist season, but recently remained open throughout the year. It was a common practice to buy sea turtle eggs from egg collectors at a rate of about 8-15 LKR (< 0.15 USD) each and bury them in an incubation enclosure within the hatchery. "Headstarting" occured at all hatcheries. Most of the rearing tanks were regularly cleaned, but crowded during the turtle nesting season. Juvenile and sub-adult turtles that had been kept for display were often released to the sea when feeding became costly. None of the hatcheries were involved in any collaborative research or provided visitor education contributing to sea turtle conservation; operations were an attraction for tourists and provided financial income for the local community.

INTRODUCTION

Sea turtle hatcheries exist as an *ex situ* conservation tool in many countries (Shanker, 1994; Upm & Perhilitan, 1996; Chan, 2001; Shanker, 2003), including the southeastern coast of Sri Lanka (Hewavisenthi, 1993; Tisdell and Wilson, 2005a). However, doubts have been raised about the effective contribution of hatcheries to the conservation of sea turtles (Hewavisenthi, 1993; Shanker & Pilcher, 2003). Tisdell and Wilson (2005a) modeled the role of tourism-based sea turtle hatcheries by combining economical and ecological parameters, and demonstrated that hatcheries can make a positive contribution to sea turtle conservation, but their effectiveness depends on their management.

Of the seven sea turtles species in the world, five (the green, *Chelonia mydas*; leatherback, *Dermochelys coriacea*; loggerhead, *Caretta caretta*; hawksbill, *Eretmochelys imbricata*; and, olive ridley, *Lepidochelys olivacea*) nest in Sri Lanka (Deraniyagala, 1953). Nesting occurs throughout the year, but March to May is considered as the nesting season with a peak in April (Ekanayake *et al.*, 2002; 2010). The south and southeast coastlines, encompassing suitable beaches and vast areas of seagrass beds and coral reefs, provide important nesting and foraging grounds (Deraniyagala, 1939; Amarasooriya, 2000). This area has a high human population and tourism is also largely concentrated along these coasts. A study conducted in 2007 indicated that many villagers from the nesting areas had eaten turtle eggs, but most of the consumption occurred during the 1990's or earlier (Rajakaruna *et al.*, 2009).

The first Sri Lankan sea turtle hatchery was established in 1956 at Yala National Park by the Wildlife and Nature Protection Society of Sri Lanka, a non-governmental organization for nature conservation. A second hatchery was established at Palatupana in 1969. Both hatcheries were opened with conservation, restoration and management of the sea turtles and their habitats in Sri Lanka as the main objectives. The number of hatcheries increased rapidly in the 1970's, with as many as 23 additional hatcheries opening (Fernando, 1977). The number of hatcheries has since varied: 16 hatcheries were recorded in 1994 (Richardson, 1995) and 25 hatcheries were listed in the proposed action plan for conservation restoration and management of turtles and their habitats in Sri Lanka in 1996 (de Silva, 1996). However, a survey conducted in 1996 recorded only seven hatcheries (Amarasooriya & Dayaratne, 1997). Wickremasinghe (1982) estimated that during 1981 and 1982 three hatcheries used 48,934 turtle eggs; IUCN (2005) estimated that nine hatcheries used ~300,000 turtle eggs in 2000.

During the 1990's, only two hatcheries in operation defined conservation as their main objective, and the remainder operated primarily for commercial gain (IUCN, 2005). The long-term success of these programs cannot be evaluated, as hatcheries rarely kept records of hatching success or tracked hatchlings once they left the beach (Hewavisenthi, 1993; Hewavisenthi & Kotagama, 1990). While the contribution of turtle hatcheries to the conservation of sea turtles was highly debated, the Department of Wildlife Conservation (DWC) in Sri Lanka considered that management techniques in operation at the majority of hatcheries were not conducive to the conservation of sea turtles (IUCN, 2005). We conducted a survey to assess the activities of current hatcheries in Sri Lanka, and the potential contribution to sea turtle conservation.

METHODS

All existing sea turtle hatcheries were included in this study. Hatcheries were visited once during the nesting off-season (02 October 2010) and again during the nesting season (28 March 2011). We interviewed the owner, or the hatchery keeper present, at the time of our visit. Verbal consent was first sought from the interviewee, after explaining the objectives of the study and presenting a permission letter issued by the DWC, Sri Lanka. Each interview lasted between 30–40 mins, and collected information about the hatchery and hatchery keeper/owner, hatchery management practices, compliance with the Fauna and Flora Protection Ordinance (FFPO, 1938 amended in 1972), and potential contribution to conservation of sea turtles.

Hatchery profile

The name, district, location, age, distance from the sea, reasons for site selection, number of current employees, number of volunteers (if any), number of incubation enclosures, number of tanks and their capacity were recorded. Information about the effect of the tsunami in December 2004 and the extent of damage to the hatchery was also collected.

Hatchery keeper/owner profile

Eight questions were asked to gather personal information about the hatchery keeper/owner to gather information about their experience as a hatchery keeper/owner and formal training in hatchery management.

Management practices of the hatchery

Twenty-seven questions were asked to assess the management practices of the hatchery: egg collection methods, number of suppliers (if relevant), site/s of egg collection, frequency of egg collection, number of eggs collected (during peak season and off-season), proportion of eggs originating from suppliers, method of transport of eggs to the hatchery, price of an egg, how the eggs are buried, number of eggs in one artificial nest, distance between nests, hatch success, turtle species currently in the hatchery (including adults and hatchlings), percentage of hatchlings that are kept in the hatchery, method of releasing the hatchlings, diet of hatchlings and adults, duration of hatchling holding time in tanks, method of hatchling release, and frequency of cleaning the tanks. Further questions were asked about visitor entry (and the entry price if applicable), souvenir sales, number of visitors

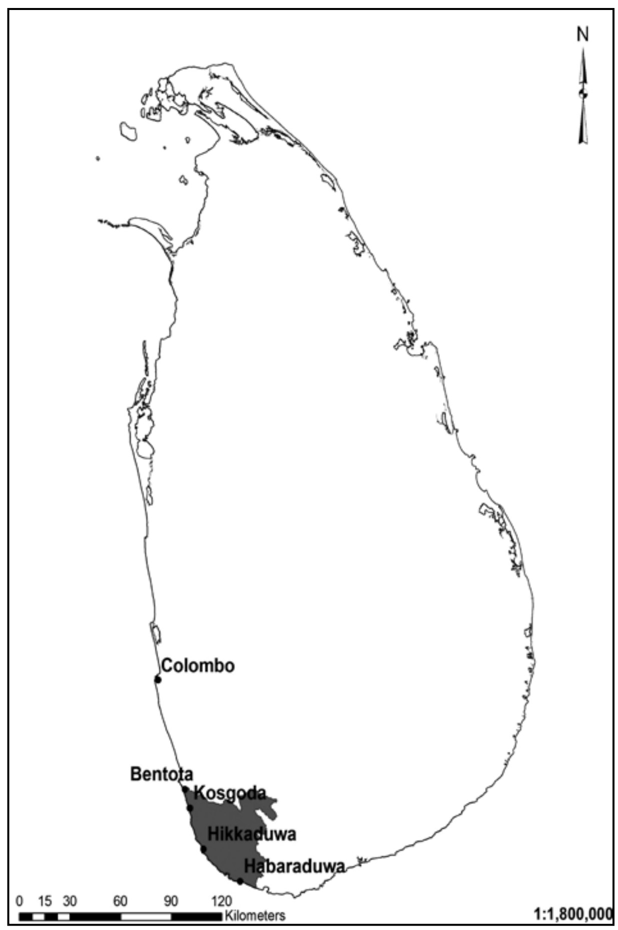

Figure 1. Hatcheries along the southwestern coast in the Galle district of Sri Lanka

a year, if visitors were allowed to touch, hold or feed hatchlings, juveniles and/or sub-adults and if visitors requested to release hatchlings for religious purposes.

Compliance with the FFPO and contribution to conservation

Compliance with the FFPO was determined by assessing interviewee awareness that possessing and/or selling sea turtles or their products was illegal, while an observation check list noted down any turtle products displayed or available for sale in the hatchery. Interviewees were also asked if they were aware that establishing a turtle hatchery was illegal. The potential contribution of the hatchery towards conservation of sea turtles was determined by asking questions about conservation awareness programs or information available for visitors, and whether they believes that hatcheries should be required to obtain a yearly license based on proper management, records of eggs collected, hatch success etc. Information about any collaborative research, prior participation in surveys and purchase of eggs during the tourist off-season was also collected during the interview. The scale of the hatchery, overall organization, health of hatchlings, overcrowding in the tanks, water condition and cleanliness, other income generating methods, beachfront, garden or street lighting, and incubating enclosures (distance between two nests, vegetation cover, amount of sunlight and shade) were also measured/observed and noted down using a checklist.

RESULTS AND DISCUSSION

At the time of the study, seven sea turtle hatcheries were in operation along the southwestern coast in the Galle district of Sri Lanka (Table 1, Figure 1).

Hatchery profile

All the existing hatcheries were operated by private owners and categorized as small, medium or large based on the total hatchery area, number and size of egg incubation enclosures, and number and capacity of tanks (Table 1). All were more than 10 years old, and five of the hatcheries were more than 20 years old. The oldest hatchery, Sea Turtle Hatchery in Kosgoda, began operations in 1963 and the most recent, Sea Turtle Farm and Hatchery in Periliya was established in 2000. All the hatcheries were severely damaged by the tsunami in December 2004, and have been subsequently rebuilt further from the sea. The Sea Turtle Farm and Hatchery in Hikkaduawa was completely destroyed by the tsunami and still does not have a proper roof, so rain water collected into the rearing tanks.

Small scale hatcheries were managed and maintained by a single person, usually the owner or a family member, while large scale hatcheries employed a varying number of people for routine maintenance (Table 1). The highest number of employees at a single hatchery was 12 people (including the owner or manager).

All hatcheries possessed egg incubation enclosures inside the premises. Egg incubation enclosures, and sometimes the total hatchery area, were fenced to protect nests from predators and poachers (Figure 2C). A varying number (usually 6–9) of cement tanks, of different sizes (1000L-5000L), for rearing hatchlings, juveniles and sub-adults were present in a roofed area (Figure 3A; Table 1). All hatcheries had three to ten individuals of three or four species of juvenile and sub-adult turtles on display. Entry tickets cost between 50 and 250 LKR (0.40–2.00 USD), and some hatcheries also had a donation box for

Table 1. Profiles of the seven turtle hatcheries operating on the southwestern coast of Sri Lanka in 2012.

Hatchery Name	Location	Years Operating	# Staff (Including Owner)	# Species	# Egg Incubating Enclosures	# Holding/ Rearing Tanks	Distance to Sea	Scale*
Wunder Bar	Bentota	16	1	4	2	7	250m	Small
Sea Turtle Conservation Research Project	Bentota	31	12	4	2	9	50m	Large
Turtle Conservation Research Centre	Kosgoda	33	10	4	2	8	10m	Large
Sea Turtle Hatchery	Kosgoda	48	10	3	2	7	300m	Large
Kosgoda Sea Turtle Conservation Project	Kosgoda	23	1	4	3	6	15m	Medium
Sea Turtle Farm and Hatchery	Hikkaduwa	11	1	3	2	8	10m	Medium
Habaraduwa Turtle Hatchery	Habaraduwa	21	5	4	1	8	20m	Small

*Based on the number and the size of rearing tanks, incubation enclosures and total hatchery area.

visitor contributions towards sea turtle conservation. Souvenirs, clothes and other items were sold to create additional income. None of the hatcheries had volunteers, local or foreign, working during our visits, although some owners said that there had been many in the past.

Hatchery keeper/owner profile

The hatchery owner, or a family member (wife/son), who was present at the time of visit was interviewed at all the operations except one (Wunder Bar in Bentota), where an employee (hatchery keeper) participated in the interview. Six of the interviewees were males and one was female; all were between 23 to 50 years of age. Most had completed education at least up to junior secondary level (until ~16 years of age). A hatchery owner with only primary school education had 33 years of experience and had undergone formal training in hatchery management from the programmes conducted by K.D. Amarasooriya of the National Aquatic Resources Research and Development Agency (NARA), Sri Lanka, and Prof. S. Kottama, University of Colombo, in the 1990s. Three hatchery owners claimed that they had participated in training programs on hatchery maintenance while others did not have any formal training but claimed that they learned either from the employer or from his/her father (Table 2).

Hatchery management practices

All hatcheries purchased eggs that were collected at night, from nearby nesting beaches, by fishermen or villagers; there were between four and 50 designated egg suppliers in some areas. Hatcheries paid 8 to 15 LKR (0.07 – 0.12 USD) for an egg, depending on the nesting season and area (Table 3). With the exception of one hatchery (Sea Turtle Conservation Research Project in Bentota), all claimed that they purchased all the eggs brought by a supplier, even during the tourist off-season. Sea Turtle Conservation Research Project reported they did not purchase all olive ridley turtle eggs as the hatch success was lower than other species. It was unknown whether the suppliers brought the eggs to hatcheries due to demand, or would stop doing so if there was no market, but Tisdell and Wilson (2005a) reported that purchasing eggs from suppliers established a market value. One hatchery owner reported that police had donated eggs confiscated from poachers in the area. Some hatchery managers themselves collected eggs from the beach.

Table 2. Profile of interviewees from sea turtle hatcheries in Sri Lanka.

Hatchery Name	Status	Age (Yrs)	Sex	Education	Hatchery Experience (Yrs)	Formal Training in Hatchery Management
Wunder Bar	Keeper	23	Male	O Levels	3	No
Sea Turtle Conservation Project	Owner	50	Male	A Levels	30	Yes
Turtle Conservation Research Centre	Owner	49	Male	Secondary	33	Yes
Sea Turtle Hatchery	Owner's Son	32	Male	O Levels	20	No
Kosgoda Sea Turtle Conservation Project	Owner	40	Female	A Levels	11	No
Sea Turtle Farm and Hatchery	Owner	35	Male	A Levels	5	No
Habaraduwa Turtle Hatchery	Owner	36	Male	A Levels	15	Yes

Table 3. Management practices of the seven turtle hatcheries in southwestern Sri Lanka.

Hatchery Name	Egg Price (USD)	# Egg Suppliers	Status of Incubating Enclosures*	% Hatchlings Released	Hatchling Holding Period	Rearing Conditions for Adults*	Water Quality*	Overall Hatchery Standard*
Wunder Bar	0.10-0.15	9	3	99	1 day	2	3	3
Sea Turtle Conservation Project	0.10	5	4	95	1-3 days	2	2	2
Turtle Conservation Research Centre	0.10-0.12	50	3	80	1-3 days	2	2	2
Sea Turtle Hatchery	0.10-0.20	30	5	75	>2 weeks	5	5	5
Kosgoda Sea Turtle Conservation Project	0.10	4	3	95	1 day	2	2	2
Sea Turtle Farm and Hatchery	0.10	4	3	95	1 week	3	4	4
Habaraduwa Turtle Hatchery	0.08-0.09	25	2	80	1-7 days	4	2	3

Despite the collection of turtle eggs from the wild being illegal, beaches were not declared as protected areas or reserves and were, therefore, open access resources. Tisdell and Wilson (2005a) argued that once eggs were collected and sold to hatcheries, they became private property and could be protected by the hatchery owners. Supporting this argument, some suggested that private ownership of wildlife might be an effective means for conservation (Swanson, 1994; Skonhoft, 1999) and this concept could also be applied to sea turtles if there was specific ownership and clear legal responsibilities (Eckert, 1991; Crowder, 2000; Witherington & Frazer, 2003).

Suppliers transported turtle eggs in plastic bags or cardboard boxes. Hatchery practice guidelines (IUCN, 2005) recommend a special container, such as a bucket or a box, be placed inside a larger polystyrene box during transport and there be minimum rotation of the eggs. Egg suppliers in Sri Lanka were not educated on how to collect, transport or handle eggs, and most of the hatchery keepers were unaware of the location of egg collection, when the eggs had been laid and when they were collected. Purchase of eggs transported in plastic bags, and from far locations, should be discouraged; eggs should be collected within three hours of oviposition and re-buried before white spots appear on the surface of the eggshell (IUCN, 2005).

Egg incubation enclosures

Eggs were buried in hand-dug nest chambers inside incubation enclosures (Figures 2A & 2B). The enclosures were well protected from predators (Figure 2C) and located several meters above the highest water mark of the diurnal tide. All hatcheries possessed two egg incubation enclosures, except Habaraduwa Turtle Hatchery which had only one (Table 1). IUCN (2005) hatchery guidelines recommended at least two enclosures within a hatchery, used alternately every six months. In order to prevent infection by fungi and bacteria, the same incubation site should not be used over two consecutive nesting seasons (IUCN, 2005). Interviewees claimed that the eggshell and unhatched egg debris were removed by hand, and the sand in the pen was changed completely or washed before re-use in a subsequent season.

Most hatcheries marked nest locations with a flagpole (Figures 2B & 2C), a label on which showed the species and the date the clutch was buried. Piling sand on top of the nest was a common practice at all hatcheries (Figure 2B) except Habaraduwa Turtle Hatchery. The sand pile was created when the egg chamber was not deep enough to accommodate the entire clutch. The average natural nest depth for each turtle species is: leatherback 90cm, green turtle 70cm, loggerhead 65cm, hawksbill 55-65cm, and olive ridley 31-45cm (IUCN, 2005); the average depth of the nests in the hatcheries was not determined. Hatchery nest depth influences nest temperature (Van De Merwe *et al.* 2006) and piling sand on the nest may also have an effect on nest temperature and subsequent hatchling sex ratios.

Figure 2B. Mounds of sand on hatchery nests

Photo credit: Lalith Ekanayake

Figure 2A. Structure and location of nests in hatchery

Photo credit: Lalith Ekanayake

Figure 2C. Egg incubation enclosures

Photo credit: Lalith Ekanayake

The Sea Turtle Conservation Research Project in Bentota did not purchase all available olive ridley eggs as the hatch success was lower than for other species. The egg incubation enclosures in this hatchery were located in an area surrounded by tall beach vegetation and received less sunlight than the other hatcheries. Olive ridley turtle nests are much shallower (31-45cm) than nests dug by other species, and are usually laid on open beaches (IUCN, 2005). A possible reason for lower hatching success in olive ridley nests in Sea Turtle Conservation Research Project in Bentota may be the effect of burying these eggs in deeper and shaded nests, creating nest temperatures below the lower threshold of tolerance for developing embryos. The proximity of vegetation and degree of shading in egg incubation enclosures should be an important consideration when choosing a hatchery location.

Variability in the thermal environment of nests can result in hatchling sex ratios different to those in natural nests (Standora & Spotila, 1985; Spotila *et al.*, 1987). Research should be conducted to determine the pivotal temperature at Sri Lankan nesting beaches, from which eggs were collected, then sufficient shade and light exposure provided at the hatchery to match this temperature as closely as possible.

At one hatchery, nests were located less than one foot apart (Figure 2B). The recommended distance between two nests is at least 2ft, to minimize their impact upon one another and to allow room for hatchery workers to move (IUCN, 2005). However, overcrowding of small enclosures with a large number of nests during the nesting season was common in most hatcheries. In one hatchery (Sea Turtle Hatchery in Kosgoda) some viable eggs were incubated for display in partially buried, open buckets (Figure 4A).

Hatchling emergence and migration

The emergence of hatchlings from the nests occurred unaided but "headstarting" (the captive rearing of turtles through an early part of their lifecycle) was practiced at all hatcheries. After a certain time (usually one day to two weeks depending on the hatchery and season) or size (once the yolk sac was fully absorbed), headstarted neonates were released into the sea where they were assumed to have improved survivorship (Heppell & Crowder, 1996; Pilcher & Enderby, 2001). Some hatchery owners believed headstarting raises hatchlings through their most vulnerable period, when they may be subject to intense predation. Headstarting of Kemp's ridley turtles in Galveston, Texas, has yielded no conclusive evidence of long-term success (Byles 1993).

Under natural conditions, hatchlings crawl rapidly from the nest to the sea following emergence (usually at night) and immediately enter a swimming frenzy that may last up to 24 hrs, during which they distance themselves from shore and shore-based predators (Wyneken & Salmon, 1992; Wyneken & Salmon, 1994). None of the hatchery enclosures allowed free migration of the hatchlings to the sea after emergence from the nest; hatchlings were trapped within the enclosures overnight. Staff recovered hatchlings the following morning and placed them in tanks. A varying proportion (75%-95%, depending on the hatchery) were released to the sea the following night, and the remainder were kept in tanks for display (Table 3). This practice does not follow hatchery guidelines (IUCN, 2005) which specify that only 5% of the total clutch of hawksbill turtles, and less than 10% of other species, should be retained in hatcheries.

All the hatcheries held their hatchlings in tanks for 24hrs or more (Figure 3B & 3C). One owner kept all hatchlings for many days, until the yolk sac was fully absorbed, as he believed the hatchlings were easy prey if they entered the sea with the yolk sac in its natural state at emergence. During this time, hatchlings swam continuously and missed valuable hours of darkness during which they would normally distance themselves from shore (Pilcher & Enderby, 2001). The disturbance to normal post-emergence behavior likely affected their chances of survival, by depleting limited energy supplies and altering their programmed swimming behavior and timing. Although newly emerged turtles displayed vigorous swimming behaviour, those held for more than 24 hrs appeared less active (personal observations). Pilcher *et al.* (2000) found that up to 50% of hatchlings from hatcheries may be lost in the first hour at sea in Sabah, Malaysia. Hatchlings demonstrated a 12% decrease in swimming speed after just six hours of retention in a hatchery. Swimming style is also known to vary with prolonged retention; hatchlings frequently used a dog-paddle swimming style with alternate flipper movements rather than the more efficient power stroke with simultaneous flipper movements after several hours of retention (Pilcher *et al.*, 2000). This deviation from usual swimming style, combined with decreased swimming speed, likely hindered hatchling offshore migration and reduces survival rates.

Turtles show a high degree of nest site fidelity, although the level of site fidelity varied between species (Miller, 1997). Nesting female turtles usually return to their natal area to nest. This indicates that some form of magnetic imprinting may occur (Pritchard, 1980) which could be impeded if hatchlings were held in tanks (Pilcher *et al.*, 2000; Tisdel & Wilson, 2002). Therefore, the free migration of hatchlings from the nest to the sea soon after

Figure 3A. Hatchling rearing tanks

Photo credit: Lalith Ekanayake

emergence is important. According to the best practice guidelines (IUCN, 2005), at least 90% of hatchlings from each nest should be allowed to immediately crawl to the sea, to promote natural imprinting. Moreover, hatchlings should not be held in tanks prior to release, and should be released within 24hrs of emerging between 7pm to 5am. Holding hatchlings for more than 24hrs should be avoided for any reason during the peak-nesting season. However, they may be kept for a maximum of seven days during the off-season (IUCN, 2005). None of the existing hatcheries followed these best practices.

Rearing of hatchlings

Hatchling should be provided with a minimum area of one square foot surface area, with a maximum stocking density of 50 hatchlings per tank; the maximum number of hatchling tanks recommended for a hatchery is five (IUCN, 2005). Most of the rearing tanks observed during our study were clean and the tank size was sufficient for the hatchlings (Table 3). However, crowded hatchling tanks were common during the nesting season (Figure 3B). Hatchlings were transferred to a separate

Figure 3B. Crowding in hatchling rearing tanks

Photo credit: Lalith Ekanayake

Figure 3C. Feeding tank

Photo credit: Lalith Ekanayake

tank for feeding (Figure 3C) at all the hatcheries. Green, loggerhead, hawksbill and olive ridley hatchlings were held in tanks, but not leatherback turtle hatchlings. The DWC does not permit rearing of leatherback turtles in a hatchery, as the species feeds on jellyfish, which are not easily accessible (DWC pers.comm.). Although the hatcheries displayed sign boards that prohibitied touching and feeding, eggs, hatchlings, juveniles and sub-adults were touched and photographed by visitors to most hatcheries. None of the hatcheries allowed visitors to feed the hatchlings, but some hatcheries allowed visitors into the incubation enclosures.

Stocking and rearing of juveniles and sub-adults

Although it is recommended that only one adult turtle be held in a single tank (IUCN, 2005), two or more juveniles or sub-adults were frequently housed in one tank at all the hatcheries surveyed (Figures 4B). Since feeding bigger individuals was costly, some hatcheries released turtles at about 3-4 years old (about a foot long). These turtles probably lacked the behavioural adaptations to avoid predators and the foraging abilities

Figure 3D. Hatchery educational material

Photo credit: Lalith Ekanayake

Figure 4A. Eggs on display
Photo credit: Lalith Ekanayake

Figure 4B. Crowded juvenile turtles
Photo credit: Lalith Ekanayake

Figure 4C. Removing hatchlings from nest
Photo credit: Lalith Ekanayake

which would allow them to survive in the wild (Pilcher & Enderby, 2001). Sea turtles can return to their wild after long periods of captivity, and many long-term captive animals have successfully re-entered their natural habitat, chosen traditional migration routes, and survived (Bell *et al.*, 2005). Satellite telemetry suggests that rehabilitated turtles were able to adapt quickly and returned to "normal" foraging areas and behavior following extended periods in captivity. However, there was significant interference in the life cycle of the turtles born and raised in hatcheries and their survival in the wild is highly unlikely (Pilcher & Enderby, 2001).

At all the Sri Lankan hatcheries, turtles were fed with easily available fish, including the herbivorous, adult green turtles. Some hatchery owners claimed they provided a mixed diet of sea grass and fish to green turtles and keep sea grass in tanks to feed the turtles.

Compliance with ordinance and contribution to conservation

During the 1990's, some hatcheries operated only during the tourist season, indicating the prime motive of the hatcheries was profit rather than conservation (Hewavisenthi, 1993). Current hatcheries operated year-round, although the number of visitors was less during the tourist off-season. Some hatcheries recently changed their name from "turtle hatchery" to "turtle conservation and research project", suggesting the primary goal of the name change was for commercial gain but with an understanding about the need for hatcheries to contribute to sea turtle conservation. Some displayed educational material for visitors (Figure 3D).

All Sri Lankan hatcheries should be licensed annually, based on the recommendations of a National Steering Committee on Marine Turtle Conservation (IUCN, 2005). During the current study, all hatcheries agreed to obtain a license, if required. Records of species, date and number of eggs buried, the date hatched and the date released to sea were previously kept by some hatcheries. However, this practice was not continued after the tsunami in December 2004 when all records were lost. Interviewees acknowledged that the lack of monitoring of hatchery practices did not motivate them to keep the records.

All interviewees were aware that possessing sea turtles or turtle products was illegal, but they were unaware that hatcheries were illegal to operate without a permit. The DWC can authorize establishment of hatcheries under section 55 of the FFPO, with special emphasis on conservation and scientific studies. A national steering committee on marine turtle conservation, with members from DWC, NARA, and CCD, should be formed to evaluate and approve the hatchery performance and give permission to issue/renew a license. However, the practices of existing hatcheries might not qualify to grant permission to operate. The primary aim in maintaining a sea turtle hatchery in Sri Lanka was as a profit oriented venture, and may not provide positive conservation benefits. Poor practices were employed at most hatcheries. However, hatchery owners and/or managers were aware of the need for sea turtle conservation. Hatcheries were often expensive to establish and maintain, and were usually located in or adjacent to villages with low socio-economic standing. They provided financial income for the community involved. Closure of existing hatcheries would be impractical, but hatchery operations should be conducted by well trained personnel under constant guidance by conservation biologists and closely monitoring by DWC. Hatchery practices should follow those of the IUCN (2005). Permission to start new hatcheries should not be granted by the DWC under any circumstances. Although establishment and operation of hatcheries was prohibited under section 30 of the FFPO, the Director of the DWC can, under section 55 of the Ordinance, authorize such activities for the purpose of protection, preservation and for scientific studies and investigations. However, sea turtle hatcheries were recommended as a last resort where in situ conservation is not possible or impractical (IUCN, 2005).

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GREEN TURTLE NESTING ACTIVITY AT JUANI ISLAND, TANZANIA, DURING THE 2012 PEAK NESTING SEASON

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INTRODUCTION

Juani Island (Figure 1) is a small island (9km long and 3.5km wide) located in the south eastern corner of Mafia Island Marine Park (MIMP) off the coast of Tanzania. Gazetted in 1995, MIMP covers 822km^2 and more than 75% of the park is below the high water mark. The marine park supports a diverse range of tropical habitats including coral reefs, seagrass beds, mangroves, intertidal flats and a strip of lowland coastal forest. The area is recognised internationally as a critical site for biodiversity (MIMP General Management Plan, 2000). There are eight turtle nesting beaches on the eastern side of Juani Island that support the largest green turtle (*Chelonia mydas*) rookery in Tanzania (Sea Sense, unpublished data). More than half (60%) of all green turtle nests in MIMP are laid on Juani Island (West, 2010a) with an average of 124 ± 45 nests per year. The beaches range from 109m to 330m in length. There are also a number of small sandy inlets, but most are submerged at high tide. Nesting activity is concentrated on four beaches (West, 2011) and occurs year round with a noticeable peak in April and May (Muir, 2005). Hawksbill turtles (*Eretmochelys imbricata*) also nest in small numbers on the southern tip of the island (L. West, pers.obs).

METHODS

In 2001, a community based nest monitoring programme was established at Juani Island. The eight nesting beaches are monitored by a Community Conservation Officer, who received training in sea turtle biology and conservation from Sea Sense, a Tanzanian registered NGO. Early morning foot patrols are conducted on a daily basis throughout the year, and the number and species of nesting turtles are recorded based on track counts (West, 2010b).

Opportunistic flipper tagging has occurred since 2004, most often when a nesting turtle was encountered during early morning patrols. In 2012, the first saturation flipper tagging programme was undertaken during the peak nesting months of April and May. Four teams of two surveyors conducted night time foot patrols between 19:00 and 06:00 hours every night, from 3rd April to 3rd June 2012 (62 nights), on the four beaches where most nesting is concentrated. Each female turtle encountered was measured (curved carapace length and width) and examined for the presence of existing tags. If not already tagged, individually numbered titanium tags (TZ series) were applied between the first and second scale along the posterior edges of the front flippers. Tags were applied after oviposition was complete, to minimise disturbance. Any nest under threat from poaching, predation or tidal inundation was relocated to a safer area above the spring high water mark (Boulon, 1999). All other nests were left to incubate *in situ*. All nests are monitored until hatching and then excavated to determine clutch size and hatching success (Miller, 1999).

RESULTS

Sixty nesting attempts were recorded, 50 (83%) of which were successful. For the purposes of comparison, Table 1 shows the number of nesting events recorded through

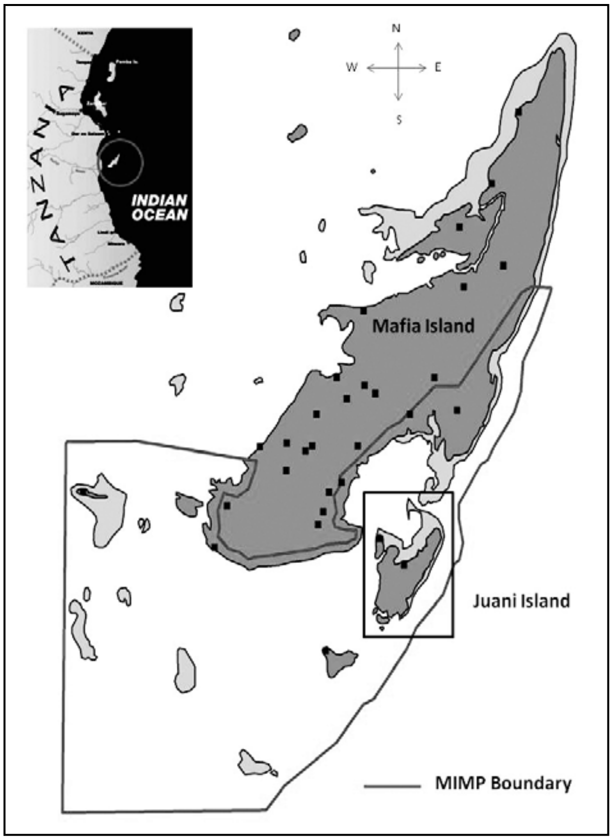

Figure 1. Mafia Island Marine Park and location of Juani Island, Tanzania.

track counts during previous years of monitoring at the same sites, with the same level of observation effort. Eighteen individual females nested during the survey period. Females were encountered during 46 (92%) of the nesting events. Six females that did not nest successfully were also encountered. CCL's ranged from 101–118cm with a mean±standard deviation of 107.2±4.7cm (n=18). CCW's ranged from 90–113cm with a mean±standard deviation of 99.7±4.8cm. Three of the turtles had been tagged in previous years. One was first tagged in 2006, and was observed again in 2009 then during this survey. The second female was tagged in 2006, and the third was tagged in 2009. Half of the nesting females encountered (n=9) nested at least three times during the survey period; two females nested at least five times. Inter-nesting intervals were calculated according to Alvarado & Murphy (1999) and ranged from 9 to 20 days (n=31) with a mean±standard deviation of 13.2±2.3 days. The observed clutch frequency (OCF) value (Johnson & Ehrhart, 1996) was calculated for each turtle encountered nesting at least once within the survey period as a mean±standard deviation of 2.5±1.2. Of the nine individuals nesting at least three times, five turtles used the same beach for each clutch. Three females used two different beaches and one individual used three different beaches. Fourteen nests (28%) were relocated. The mean clutch size was 134±14 eggs, with a hatch success of 71%.

CONCLUSION

Prior to the saturation flipper tagging programme in 2012, estimates of the number of green turtles nesting in Juani Island had been calculated using track counts from daily patrols and breeding frequencies quoted in published literature. While track counts are a very useful method of estimating nesting population size, detailed observation of nesting behaviour was essential to begin to build a more accurate and nuanced picture. The survey not only provided accurate information on nest numbers and the number of individual females, but also the first data on clutch frequencies and inter-nesting intervals for any turtle nesting population in Tanzania.

Due to high levels of natural inter-annual variability in green turtle nesting numbers (Broderick *et al*., 2001), annual monitoring programmes are critical to detect trends in populations. It takes many years for sea turtles to mature and reproduce so populations are slow to recover from population losses. Hence it is critical to determine population trends at the earliest opportunity.

Funding for a repeat saturation tagging programme in 2013 has already been secured. Efforts will be made to secure additional funding for future years to build understanding of remigration intervals, which can provide crucial information on

Table 1. *Chelonia mydas* nesting activity at four key nesting beaches, Juani Island, 2004 to 2011.

	YEAR							
	2004	2005	2006	2007	2008	2009	2010	2011
No. nests in peak season (Apr – May)	33	34	58	29	42	41	84	76
Total no. nests per year	70	75	120	54	143	141	173	141
No. nests in peak season as % of whole year	47	45	48	54	29	29	49	54

recruitment, longevity and survivorship within the population (Broderick *et al*., 2002).

There remains a paucity of data on post-nesting migratory patterns and the location of important foraging grounds used by green turtles with natal origins in Tanzania. To help acquire this information, satellite tags were attached to four nesting females at the end of the flipper tagging programme in 2012. Preliminary results indicate a marked difference in the migratory behaviour of the four individuals. Two of the turtles undertook short distance migrations to foraging grounds less than 120km from their nesting beaches. In contrast, the other two individuals proceeded north along the east African coastline to foraging grounds in Kenya and Somalia, a distance of up to 2,000km from the nesting beaches. Daily beach patrols, flipper tagging and satellite telemetry studies are contributing to a greater understanding of green turtle nesting populations in Tanzania. More than half of all recorded green turtle nests in Tanzania are laid at Juani Island (West, 2010a) so data from a continuous and focused monitoring programme can also be used to determine population sizes at other nesting sites in Tanzania where only track counts are available (Alvarado & Murphy, 1999).

ACKNOWLEDGEMENTS

Thanks to Sea Sense Conservation Officers and to members of Juani village for their efforts in monitoring the green turtle population during the peak season. Thanks also to WWF for funding the flipper tagging and satellite telemetry programme.

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LEATHERBACK TURTLES ON THE MAINLAND COAST OF INDIA

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Leatherback records have been few and far between on the mainland coast of India. Interviews with fishermen over the years suggest that leatherbacks do, or did, nest along much of the Indian coast, but the numbers have not been large, at least not in the last century (see Shanker and Choudhury, 2006). In fact, in his guide to the Marine Aquarium in Madras, Henderson (1913) writes that the 'leathery turtle' is rare on the South Indian coast (see Frazier, 2011). He notes that a specimen was captured on the Guntur coast in April 2011, but was not brought to the aquarium.

However, local fishermen in Kerala had informed T.H. Cameron, an English officer stationed in Quilon, that a large number of leatherbacks were caught at the turn of the century but the numbers had already declined (Cameron, 1923). According to them, about 40 turtles were caught annually either while coming ashore or with nets at sea. They were often seen in the vicinity of Tangacheri Reef. Cameron attempted to obtain a leatherback specimen and finally located one, but it was sold while being transported from his office, probably for consumption.

Most of the fishing net capture and stranding records are from the Gulf of Mannar in Tamil Nadu, Kerala, and Maharashtra. While the records may not reflect actual distribution, the higher frequency of occurrence in southern India may not be surprising given that the nearest extant rookery is in southern Sri Lanka (Ekanayake *et al.*, 2002). While most records have been of captured or stranded turtles, Jones (1959) recorded a nesting event at Calicut, Kerala, in July 1956.

Southern Kerala is one of the few places in the world where leatherback meat is consumed. As recently as 2002, a leatherback turtle caught in a gill net at Vizhinjam was butchered and the meat transported to a nearby market for sale at Rs. 20 per kg (Krishna Pillai, 2003a, b). On another occasion, a captured leatherback was released due to the efforts of a foreign tourist who was present at the harbour (Krishna Pillai *et al.*, 2003a).

Additional leatherbacks have been released through the efforts of the community or forest officials (Krishna Pillai *et al.*, 2003b; Balachandran *et al.*, 2009). The most recent records of leatherback strandings are from the Gulf of Mannar (Balachandran *et al.*, 2009) and Vizhinjam (Anil *et al.*, 2009), both in 2008. In both cases, the turtles were rescued from fishermen with the help of forest officials and released.

Krishna Pillai has compiled lists of leatherback records on the Indian mainland (Krishna Pillai and Thiagarajan, 2000; Krishna Pillai *et al.*, 2003a). Table 1 contains an updated record of all leatherback sightings and strandings on the mainland coast over the last century.

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Table 1. Leatherback records on the mainland coast of India from 1923 to 2012.

Date & Year	Location	Carapace Length (cm)	Carapace Width (cm)	Plastron Length (cm)	Plastron Width (cm)	Flipper length Fore (cm)	Flipper length Hind (cm)	Head length (cm)	Sex	Weight (kg)	Stranded/ Caught (gear)	Reference
1923	Off Quilon	-	-	-	-	-	-	-	F	-	-	Cameron, 1923
1959	Calicut	190.5	-	116.8	-	-	-	-	F	-	-	Jones, 1959
1976	Visakhapatnam	-	-	-	-	-	-	-	-	-	-	Dutt, 1976
1982	Kovalam Madras	195	119	162	102	110	85	-	F	-	Stranded	Anonymous,1982; Rajagopalan,1983
1985	Devbag, Malavan	149.8	109	142.5	72.5	-	-	-	F	-	Stranded	Karbhari, 1985; Karbhari et al., 1986
1988	Mandapam	152	81	144.5	83	96	58	-	M	260	Gillnet	Rao et al., 1989
1989	Pamban	162	86	150	87	102	78	37	F	300	Trawl net	Krishna Pillai & Kasinathan, 1989
1991	Rameswaram	174	120	-	-	180	-	34	F	350	Trawl net	Krishna Pillai et al., 1995
1991	Colachel, Kanyakumari	173.2	132.4	154.7	86	106.7	68.8	39.1	F	250	Boat seine	Ebenezer & Joel, 1992
1998	Vizhinijam	150	-	108	78	100	78	39	M	250	Gillnet	Krishna Pillai & Thiagarajan, 2000
2001	Kovalam	93	68	-	-	-	-	-	M	110	Shore seine	Krishna Pillai et al., 2003a
2002	Vizhinjam, Kerala	141	106	-	-	-	-	24	F	-	Gillnet	Krishna Pillai, 2003a
2002	Pallithura, Kerala	-	-	-	-	-	-	-	F	-	Shore seine	Krishna Pillai, 2003b
2009	Manakudi	-	-	-	-	-	-	-	-	-	Tied to pillar	Balachandran et al., 2009
2009	Vizhinjam	170	80	-	-	89	-	25	-	-	Gill net	Anil et al., 2009

THE LOCAL OCEAN TRUST: WATAMU TURTLE WATCH BY-CATCH NET RELEASE PROGRAMME

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INTRODUCTION

In 1998, Watamu Turtle Watch (WTW) launched a compensatory release programme for sea turtles incidentally caught as by-catch by artisanal fisherman, in the Watamu area. The programme was first established in response to the high number of sea turtles being captured and consumed by local communities and has gone from strength to strength since it began.However, compensating fishers for turtle release is not without opponents within the turtle research and conservation community.

WTWs programme does not promote the deliberate capture or selling of sea turtles. A nominal fee (approx. $3.50 US Dollars, dependent on size) is offered in exchange for the safe release of any sea turtle accidentally captured by fishermen. This amount is significantly less than the high price turtles command on the lucrative illegal market for meat, oil and carapace, as there is still high local demand for these products some fishermen continue to harvest turtles. The By-catch Net Release Programme operates along 25km of coastline incorporating it across the 11km Mida Creek with its many channels.

Mida Creek (Figure 1) is a saltwater inlet surrounded by a mangrove forest, within the Watamu area. The creek and associated lagoons, where coral, sea grass and mangrove habitats are found, provides ideal foraging areas for juvenile green and hawksbill sea turtles all year round.

Local fishermen rely on the creek as their main source of income. With the influx of people to the coastal regions, the area is now quite heavily fished, leading to lower catch rates. The mangroves also play an important role as nurseries to a number of other marine species.

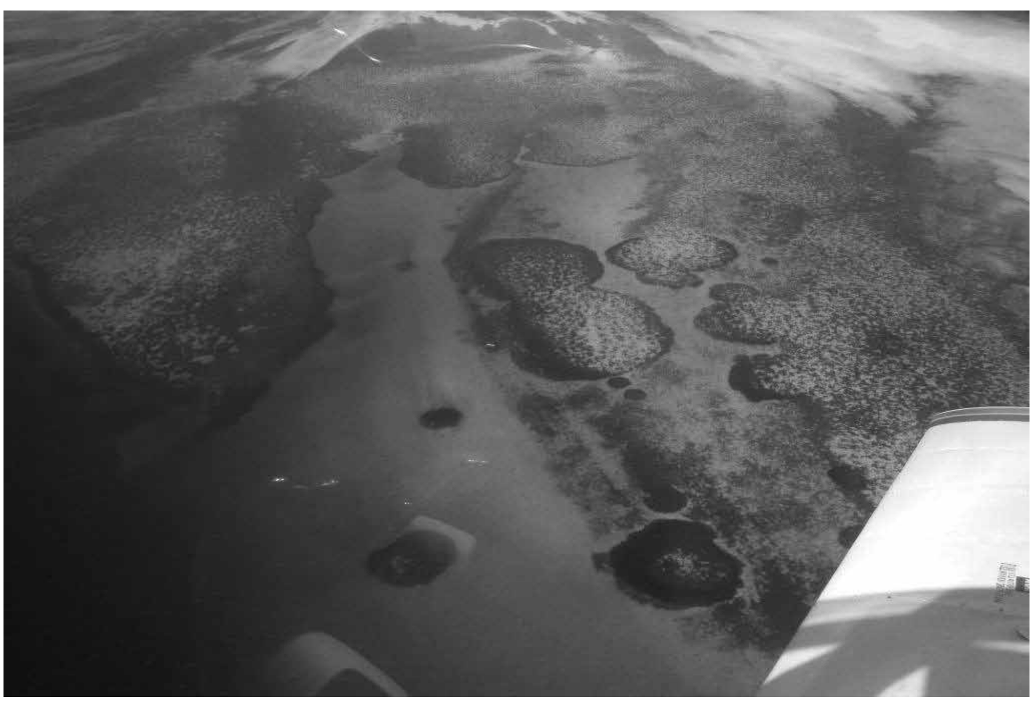

Figure 1. Mida Creek foraging habitat for juvenile green and hawksbill sea turtles.
Photo credit: Rachael Oman

The By-catch Release Programme

There are strict protocols that must be adhered to when dealing with sea turtles within this programme. This is essential to ensure our procedures are standardized and the LOT Team is able to deal with a wide variety of situations as and when they may arise.

When a turtle is caught in a fishing gear, the fisherman extricates it, calls the by-catch hotline number and then returns with the turtle to his landing site. Although fishermen were made aware of how best to minimise stress to the animal while awaiting the arrival of the WTW team, sea turtles were still being 'flipped' onto their backs in order to immobilize them. In response to this, holding boxes were constructed and made available at each of the landing sites to contain turtles awaiting release. A WTW team member attends each release, assesses the sea turtle for any signs of injury, disease or parasites, collects biometric data (Figure 2) and tags the turtle. The fisherman is then compensated for their time and effort with the amount being determined by the size of turtle. The turtle is then transported to a safe point on the beach and released (Figure 3). If the turtle has external parasite infestation, e.g. barnacles or leeches, they are removed in the field if possible; if the infestation is extensive, or the turtle is sick or injured, it is brought back to LOT: WTWs rehabilitation centre for further assessment by the veterinarian, who advises on treatment and follow up care where necessary.

The turtles that exhibit symptoms of ill health such as dehydration, fatigue, fibropapillomatosis, malnutrition or injury are admitted to the Local Ocean Trust's Sea Turtle Rehabilitation Centre for diagnosis and treatment, after which they are released. To our knowledge, the centre is the only such facility in Eastern Africa and has treated over 170 turtles, out of which more than 70% have been successfully released.

Figure 2. Fisherman assisting in weighing large green turtle
Photo credit: Rachael Oman

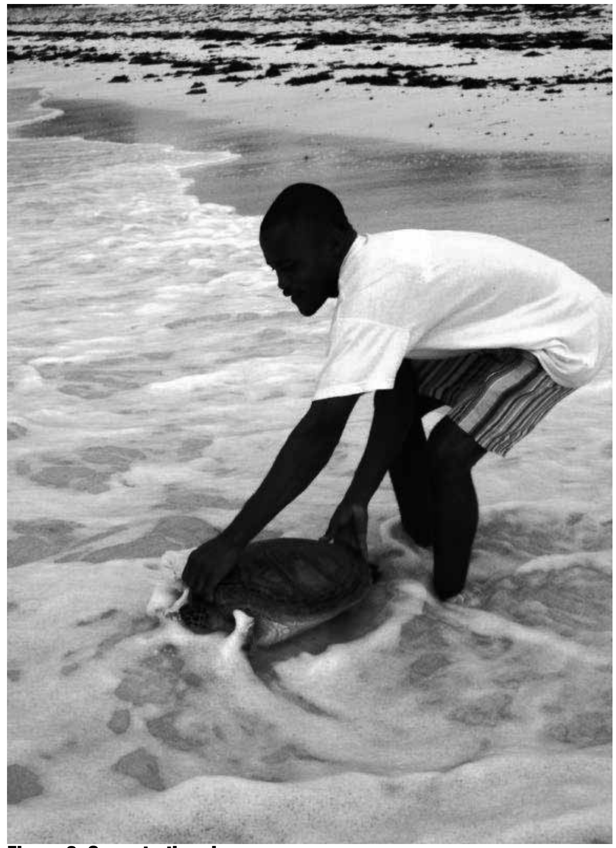

Figure 3. Green turtle release
Photo credit: Rachael Oman

Jiwe, a large male green turtle, was admitted to the rehabilitation facility after being severely injured (Figure 4) by fishermen who had caught him in nets at sea. The turtle was dragged on to the beach from their boat where he was beaten with a rock until local residents stepped in and brought him to the LOT rehabilitation facility. Unfortunately the injuries this turtle sustained were too severe and it died. This tragic outcome clearly demonstrates the need for LOT: WTW and for sustained education and awareness within the community.

During releases it is sometimes necessary to break the fisherman's hooks or nets in order to release a sea turtle safely. If this is necessary and is carried out by a member of the LOT team, hooks are replaced. The LOT team also carries string to repair fishing nets where necessary. We do not, however, fully compensate fishers for the damage a turtle may cause to fishing gears as this can vary in cost.The programme does not amend or increase the compensation amount as this sets a precedent for people to demand increased compensation on a regular basis.

Figure 4. Jiwe, a large male green turtle admitted to the rehabilitation facility
Photo credit: Rachael Oman

LOT team members have recently been given information by a number of fishermen who have been approached and asked for live sea turtles to be shipped to Mombasa from the Watamu area, in order to be killed in a specific way to be sold to Muslim and far eastern markets, where the demand is high. There is indication that the demand for sea turtle meat and artifacts is on the rise in many cities around the world, including countries in the Far East. As this local information is anecdotal, the LOT team continues to explore ways to gather evidence of emerging markets for turtle products in the area.

How Far Have We Come?

The By-catch Net Release Programme has come a long way since its inception in 1998. Emerging against a backdrop of limited funding and support, the program conducted 16 turtle releases in 1998 with participation from 14 fishermen. By 2011 the project had grown exponentially with 1,365 turtle releases conducted in cooperation with over 300 fishermen. With 1,638 turtle releases conducted by the 31st December 2012 has registered the highest annual total of turtle releases to date. Since the programme began, a total of 9,015 sea turtle releases have been conducted in total (Figure 5). All healthy turtles are flipper tagged prior to release. This is essential as it allows the LOT team to monitor individual turtles and turtle population dynamics in the Watamu area. Between 1998 and 31st December 2012, a total of 4,387 turtles had been tagged. In the last 5 years 2006-2011), a total of 2,602 turtles have been tagged compared to 458 tagged over the first 5 years the program ran (1998-2002). The total amount of compensation that has gone into the fishing community between 1998 and 2011 isKES 2,764,850 (approx. $33,000 USD). The project feels the relatively high cost of the programme does not outweigh the benefits of having such an initiative in place. In addition to the obvious economic benefits to the local community, the data collected through this programme has also enabled LOT:WTW to estimate population sizes within Mida creek and recent analysis suggests that this population has been steadily increasing. In 2006/2007 we estimated a sea turtle populationof 1,579, which rose to 3,993 by 2010/2011, perhaps suggesting that this programme is having a positive impact on the number of protected sea turtles in local waters. All data gathered is now efficiently stored in a bespoke database where dates, species, tag ID's, catch sites, fishermen's details, payment etc. are all recorded. This system allows project staff to check tag numbers, track capture sites of specific turtles, identify key foraging areas within Mida creek and 'hot spots' for fibropapillomatosis.

SUMMARY

Many people have asked the following questions, "If you have been conducting successful education and

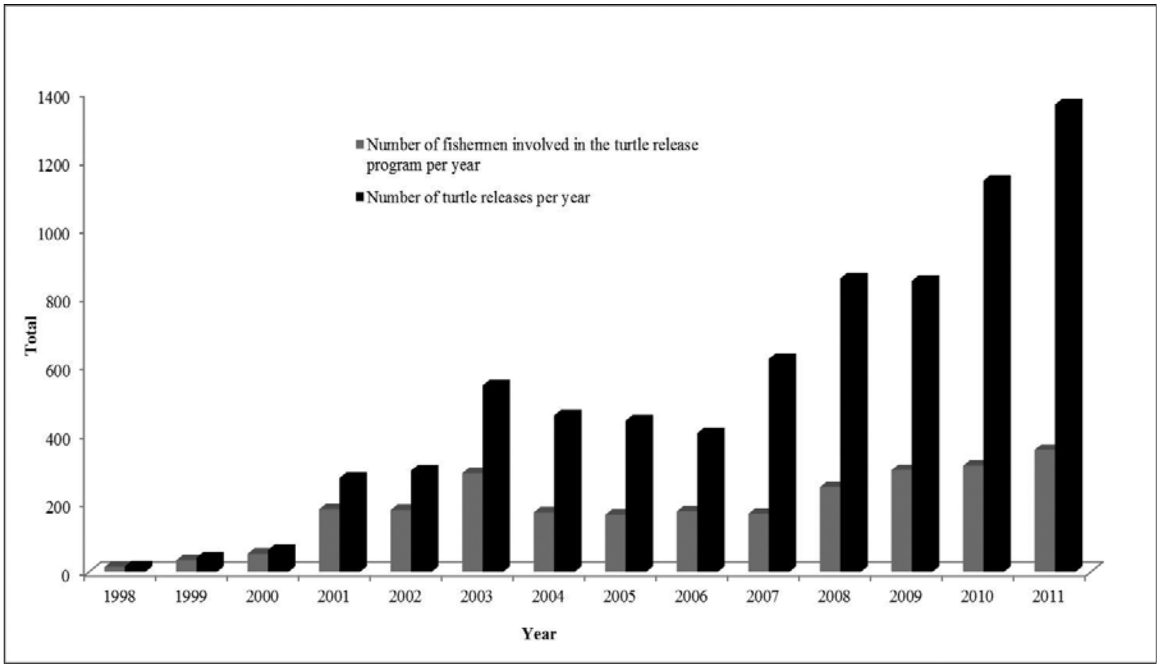

Figure 5. Annual number of fishermen involved in the turtle by-catch release programme and turtles released per year.

awareness in the community for over 10 years, why do you still need the by-catch programme?" and "Why are the fishermen not setting the turtles free without payment?"

LOT: WTW work very hard to change people's attitudes towards marine conservation, however the LOT team is well aware that the socio-economic pressures on these people are immense. Turtles can cause major damage to fishing nets which can have devastating impacts on a fisherman's livelihood. With local catches at an all-time low, many fishermen cannot afford to lose out on days of fishing due to broken nets. Conservation initiatives throughout the world face an enormous challenge in expecting people who live hand to mouth, to give up

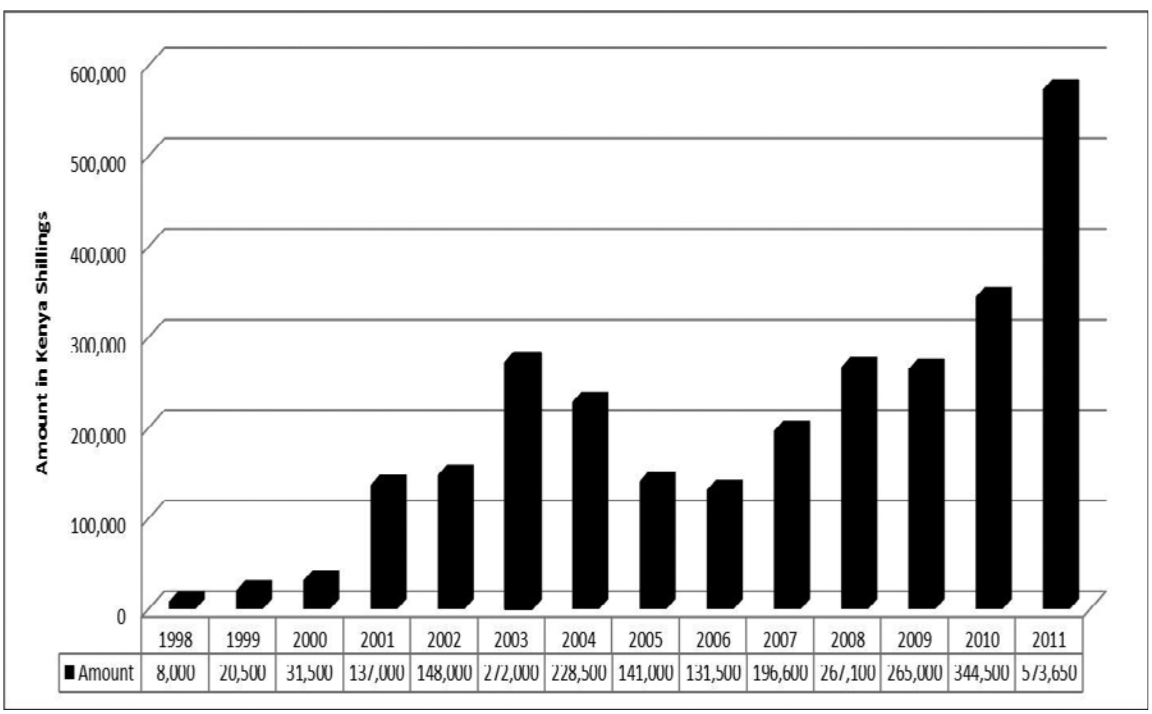

Figure 6. Annual amount of money paid to fishermen for exchange of by-catch sea turtles.

a meal for themselves and their family or lose a day's fishing for the sake of conservation. Not only that, but with the cost of living increasing, the economic pressure on households is now more intense than it was10 years ago. The meat from a single green sea turtle, measuring 1 metre, can fetch over 10,000 shillings (over $115 USD) when traded illegally. A sea turtle of this size can also yield up to 8 litres of oil, each litre being sold at 3000 shillings ($35 USD). Even if a turtle is not sold, it represents a meal that can feed a family, in a time where over fishing is seeing catch levels fall and competition between fishermen high.

Despite these pressures and the potential economic benefits of trading illegally in turtle products, many local fishing communities embrace the LOT: WTW conservation initiatives and the LOT team believe that this is why they are seeing a steady increase in the number of fishermen joining the programme and the number of turtles being released. The project has not raised the level of compensation even though the price of turtle meat and other products continues to rise. Keeping the level of compensation low avoids the risk of encouraging people to actively catch sea turtles.

However, LOT: WTW believes that, without an incentive, sea turtles would not be released. Ongoing education and awareness is vital to the success of the by-catch programme. The project continues to work closely with fishing communities and is currently engaged with 26 local schools based around the fish landing sites. The children learn about the importance of the marine environment and seaturtle conservation. Maintaining a good relationship with local fishing communities is the key to success of the programme.

A quote…

"*I have been fishing all my life, fishing is in my blood. I have seen with my own eyes that there are less fish to catch and there are less turtles than when I was a boy. I survive because of the ocean. I joined the by-catch programme as a way of 'giving back' to the ocean for all it has provided for me.*"

~ Gona Kazungu ■

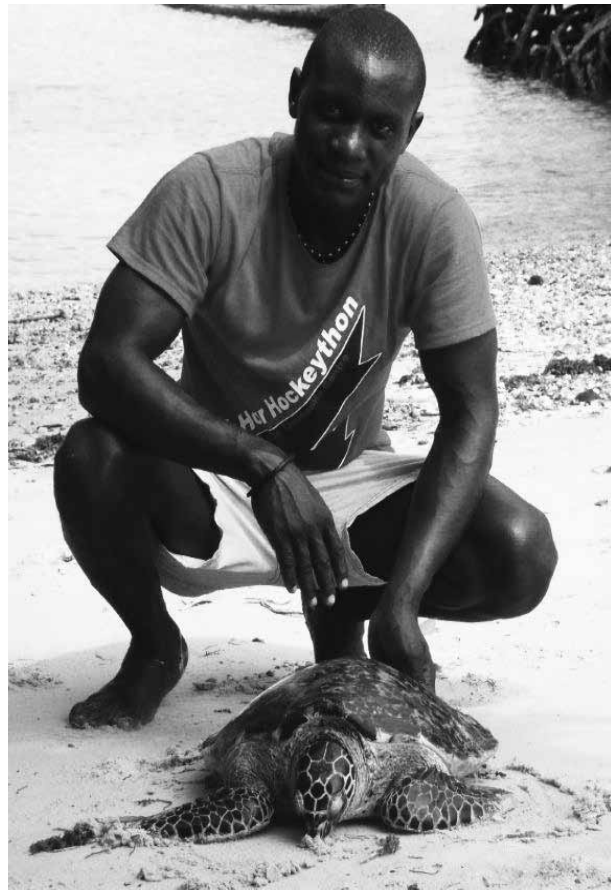

Figure 7. Gona Kazungu, Uyombo fisherman involved in Watamu turtle by-catch net release programme since 2008.
Photo credit: Rachael Oman

UTILITY OF SEA TURTLE PHOTO ID TECHNIQUES: THE EXAMPLE OF A MALE HAWKSBILL IN KUWAIT

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INTRODUCTION

Sea turtles are long-lived, slow to mature marine reptiles (Chaloupka & Musick, 1997) that undergo seasonal reproductive migrations that may span thousands of miles (Plotkin, 2003). The ability to re-identify an individual over time and in different locations improves our understanding of sea turtle life history, which in turn, informs management and conservation actions for their protection.

The application of flipper tags is a technique that has been used for many decades to bestow an identity on individual sea turtles in capture-mark-recapture (CMR) programmes. Analysis of CMR data has helped reveal many important facets of sea turtle biology and ecology (Balazs, 1999). In the last decade, satellite tracking has become increasingly used to reveal detailed insights into sea turtle migration and diving behaviour (Godley *et al*., 2008). However, sample sizes for these studies are often limited due to financial constraints of costly satellite transmitters and data (Godley *et al*., 2008).

Photo ID of sea turtles has been proposed as a cheap and reliable method for re-identifying individuals (Lloyd *et al*., 2012). The technique has been used for leatherback turtles (*Dermochelys coriacea*) for which the shape of the pink pineal spot acts as the distinguishing feature (Buonantony, 2008). The stable pattern of facial scales has been used for loggerhead turtles (*Caretta caretta*; Schofield *et al*., 2008), green (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*; Reisser *et al*., 2008).

METHODS

The Kuwait Turtle Conservation Project (KTCP) undertook fieldwork from 2008-2011 on Qaru Island (KTCP 2011). The project recorded hawksbill and green turtle nesting on the Islands of Um Al-Maradim and Qaru. KiwiSat 101 Satellite transmitters were attached to four green and four hawksbill turtles in order to ascertain foraging habitats away from nesting areas. All were adult females (Rees *et al*., In press; KTCP unpublished data). A catalogue of reef species (from corals to reef fish), mainly at Qaru, was also created as part of the project and included photo records of all species observed.

RESULTS

In July 2009, during the reef cataloguing work, an adult male hawksbill turtle was photographed swimming over the reef at Qaru. This individual was observed and photographed swimming over the reef at Qaru again in June 2010. In addition to a characteristic head scale pattern, this turtle had a clear 'paw' shaped set of scales on its hind left flipper which aided its identification (Figure 1a).

Supplementary results

A simple internet search for 'turtle' and 'Kuwait' revealed numerous files, photographs and PowerPoint presentations that matched these terms. One 'hit' from Flikr (Alsabah, 2011) revealed a photo of a male hawksbill turtle taken at Qaru on 14 October 2011 (Figure 1b). This was confirmed, from visual assessment, as the KTCP adult male, thus extending his association with the reef for a further year.

Another 'hit' linked to a PowerPoint presentation (Alsaffar & Al-Tamimi, 2006), which, on inspection, revealed a slide of a male hawksbill turtle in the section on Qaru. Examination of the animal's head scales and the scale pattern on its hind left flipper confirmed it to be the turtle identified by the KTCP (Figure 1c). The individual's association with the reef therefore pre-dated its first observation by the KTCP by at least three years.

The final discovery came from a book on coral reef habitats in Kuwait (Carpenter *et al*., 1997). Page 20 showed a dark image of a hawksbill turtle labelled 'a

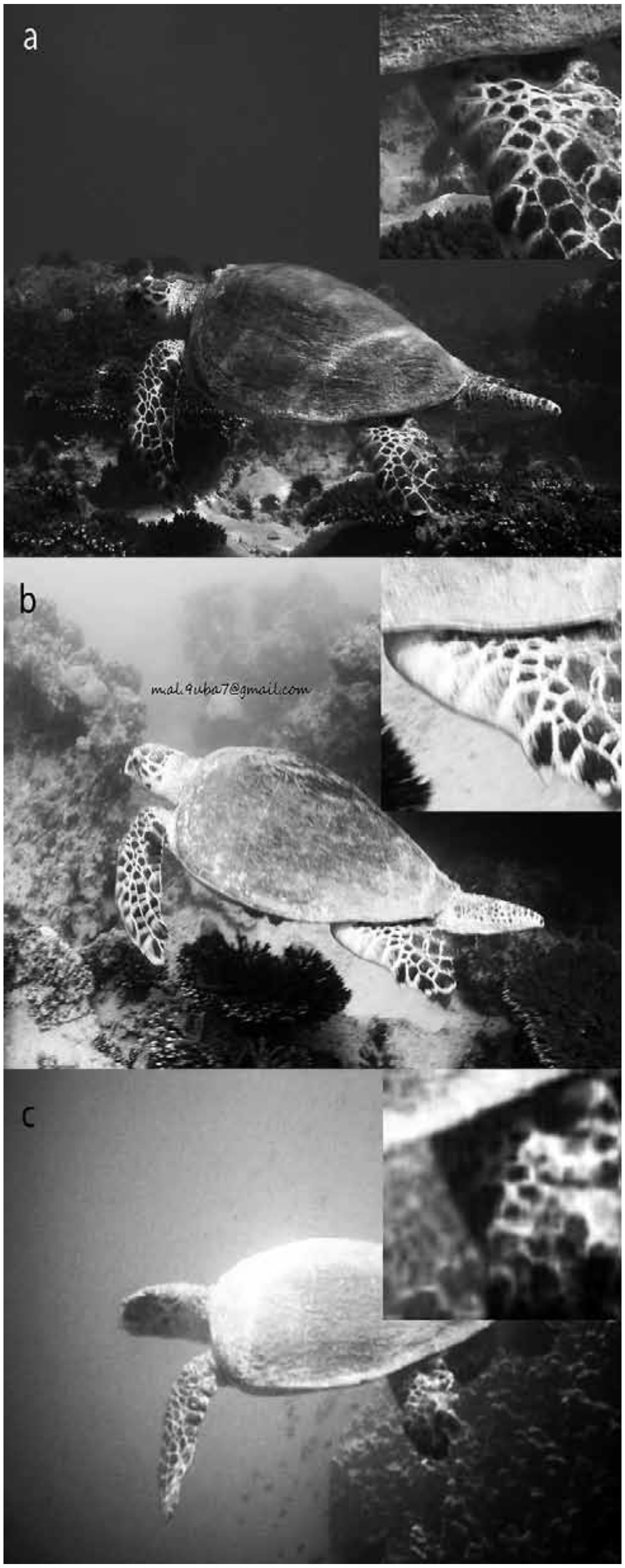

Figure 1. Adult male hawksbill turtle seen at Qaru Island, Kuwait.

a) July 2009. Photo: ALan F. Rees.
b) October 2011. Photo: Mohammad Alsabah.
c) ≤1997. Photo: Peter L. Harrison; in Carpenter et al. (1997).

marine turtle at Qaro reef'. This was the same photo used by Alsaffar & Al-Tamimi (2006). The book's publication date of 1997 extends the male's association with Qaru back a further nine years with photographic records of him in the area totalling 14 years.

DISCUSSION

These results confirm the utility of photo ID techniques for long-term sea turtle monitoring, where every photograph, taken for research or pleasure, can contribute to our understanding of their movements and residency. Further, it is poignant that only one adult male hawksbill turtle appears to have been photographed around Qaru Island in over a decade, which may indicate he is the sole male contributing to the Island's small breeding population. A genetic investigation of nesting hawksbills and their offspring, combined with genetic characterisation of this male, could support or refuse this hypothesis. If true, this individual is key to the current viability of the population and highlights the importance of protecting the habitat in which he has been found over the past 14 years.

ACKNOWLEDGEMENTS

The project was carried out under the auspices of HH Sheikha Amthal Al-Sabah and the Voluntary Work Centre of Kuwait. The project was sponsored by Total Foundation and Total Kuwait and was carried out in collaboration with the Scientific Centre of Kuwait and the Kuwait Coast Guard. We wish to thank Mohammad Alsabah for his photo and the anonymous reviewer who helped improve the manuscript.

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PAKISTAN WETLANDS PROGRAMME'S MARINE TURTLE CONSERVATION EFFORTS ON DARAN BEACH, JIWANI, PAKISTAN

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INTRODUCTION

Pakistan Wetlands Programme was launched in July 2005, with a broader goal of conserving globally significant wetlands biodiversity in Pakistan. The project embarked upon an ambitious portfolio with 10 outputs and 86 sub-outputs to achieve its two objectives of: a) Creation of an enabling environment at the national level through capacity-building and training, awareness raising, communication and environmental impact assessments; and b) Developing replicable models in the four wetlands eco-regions of the country including the Makran Coastal Wetlands Complex (MCWC), Central Indus Wetlands Complex (CIWC), Salt Range Wetlands Complex (SRWC) and Northern Alpine Wetlands Complex (NAWC). The sub-set of activities under the second objective included conservation of marine turtles at Dharan Beach, one of the marine turtles nesting grounds on Makran Coast in Balochistan Province (Figure 1). The conservation efforts on Dharran Beach included patrolling the beach, safe release of hatchlings and satellite telemetry of marine turtles.

Five species of marine turtle are recorded from the coastal waters of Pakistan. Dominant among them is the green turtle (*Chelonia mydas*), which breeds regularly on beaches of Sindh and Balochistan provinces. The other four species, including olive ridley, loggerhead, hawksbill and leatherback turtles. are rarely observed. The WWF-Pakistan's Pakistan Wetlands Program (PWP) conducted a study of their biology to identify threats to turtle populations and nesting beaches on the Makran Coast in Balochistan. Satellite telemetry was conducted by PWP to determine what threats nesting green turtles of the Makran Beach may face elsewhere and to determine their migration routes and feeding grounds. This article describes the efforts of the PWPat Daran Beach to conserve the nesting population of the green turtles.

Makran Coastal Wetlands Complex (MCWC) extends westwards along Baluchistan's Makran Coast from the Basol River to Jiwani on the border with Iran. Local communities are dependent on fishing and port activities that have led to pressures on marine biodiversity through over-harvesting and pollution. This has impacted the populations of green turtles and olive ridleys nesting along that Coast. The Programme worked with the local community of Daran to conserve the nesting beaches of green turtles there by motivating and raising awareness in the local community, capacity building and training, and by providing incentives to enhance community development and alleviate poverty.

METHODS

To establish a conservation model, the Pakistan Wetlands Programme (PWP) adopted a multi-pronged approach that included conservation, research and development initiatives.

I. Conservation and research on the nesting beach

The PWP identified key nesting sites of marine turtles, among which Daran is one of the most significant sites on the Makran Coast, and in early 2007 initiated its marine turtle conservation program on the Makran Coast. The PWP conducted surveys on previously unsurveyed sections of the Makran Coast and identified six new nesting sites.

In 1999, before the PWP, WWF Pakistan had initiated conservation of green turtles in collaboration with the Daran community. Most of the work was on one beach of Daran. With inception and launching of the Makran Coastal Wetlands Complex, the PWP took over the marine turtle conservation program from WWF Pakistan. It later extended its jurisdiction to three beaches of Daran, which are owned by the Daran Community. Green turtles are commonly found nesting on the sandy beach at the foot of the cliffs, about 10 km south east of Jiwani. This area is divided into five

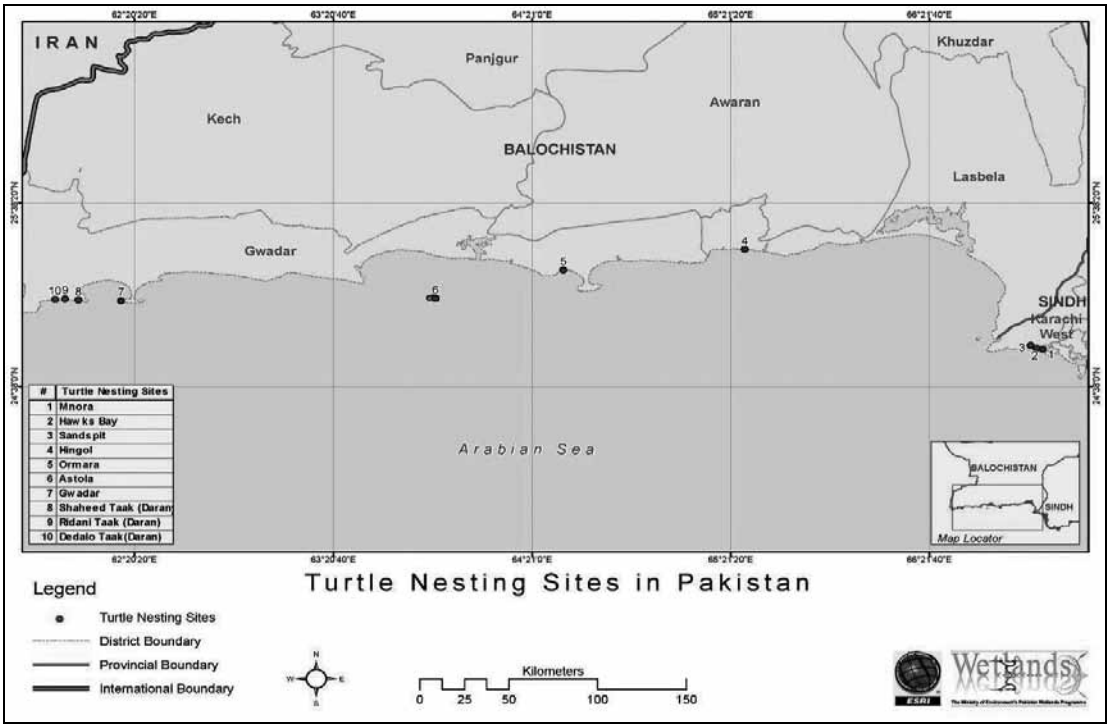

Figure 1. The Makran Coastline, Balochistan Province, of Pakistan

consecutive parts from east to west, separated by cliffs: Daran Taak, Shaheed Taak, Jangan Taak, Deedlo Taak and Picnic point. Each part extends for around 1.5km to 2km. The PWP conducted its conservation efforts on the beaches of Daran Taak, Deedlo Taak, and Picnic point. The Daran village is situated in the eastern side of Jiwani city, which is close to the Iranian/ Pakistani border (Figure 1). It has sandy cum rocky beaches and most land cover is calcareous rocky bed. The livelihood of the local community is agro-pastoral in nature with fishing to subsidize their livelihoods. The local human population is not more than three hundred and all three beaches stretch on six km.

According to findings, particularly from 2010 and 2011, the nesting season on Makran Coast starts in July, peaks in November, and declines after February (Figure 2). To protect egg clutches and hatchlings from their natural

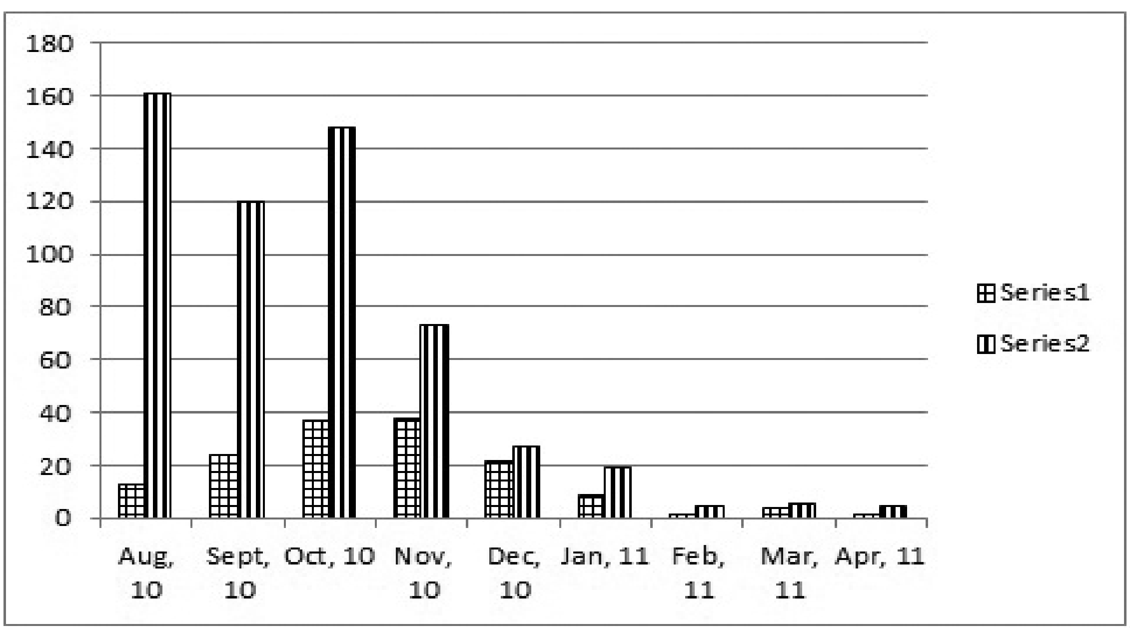

Figure 2. Monthly nesting of green turtles on Daran Beach, Pakistan

predators which include sea gulls, crows, jackals, foxes and dogs, six turtle watchers were recruited from the local community. From July 2007 through 2012 the watchers patrolled the area at night during the breeding season from July until April/May. During their patrols, the turtle watchers monitored female turtles as they emerged from the sea and nested on the beach. On completion of nesting, the turtle watchers placed a wire-mesh enclosure on each nest, with nest being labeled with a number, date of nesting and expected hatching date. They also recorded this information in their register (Figure 3).

Around the expected hatching date, the turtle watchers monitor the nest in the early morning to release any hatchlings that emerged from the nest and accumulated in the wire-mesh enclosure. The usual mortality rate during travel of hatchlings from nest to sea, usually 30% to 40%, was completely eliminated by the patrolling and monitoring of nests with subsequent safe release of hatchlings to the sea. In addition, the turtle watchers dug up the contents of the nest after hatchling emergence and counted how many eggs hatched successfully and how many failed. Record were maintained on numbers of egg clutches laid, number of unsuccessful nesting attempts, and rates of hatching success at nest sites.

Figure 3. Enclosures to protect seat urtle nests at Daran Beach, Pakistan
Photo Credits: Ahmad Khan

From October 2007 through April 2011, a total of 2580 nests were protected, from which ~26,000 hatchlings were safely released to the sea (Figures 4 and 5). The 3368 eggs laid in November 2008 was the highest number of eggs laid in a month. The number of nests recorded during the study period was different across the year indicating the fact that the population of the nesting turtles was fluctuating.

II. Satellite tracking of post-nesting females

To understand the post-nesting migrations of marine turtles nesting at Daran beach, a satellite telemetry study was conducted. A total of 15 female green turtles were tagged with Telonics A1010 transmitters during 2009-2012. The transmitters were attached to the second and third vertebral scutes of the carapace with 3M marine

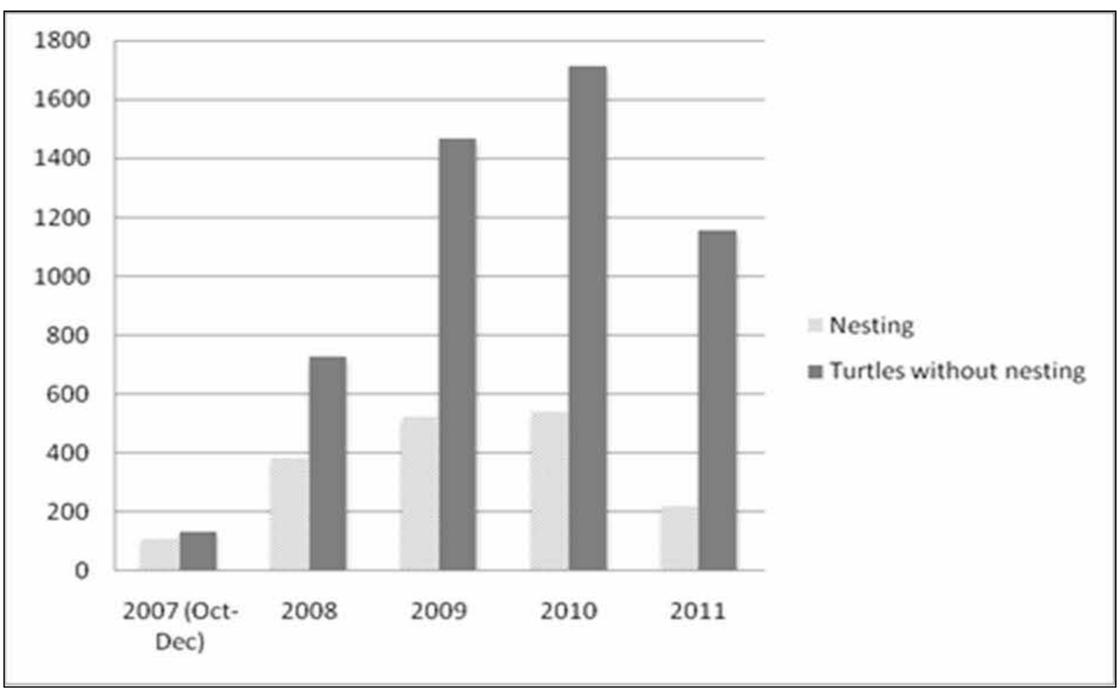

Figure 4. Successful and unsuccessful nesting of green turtles at Daran Beach, 2007-2011

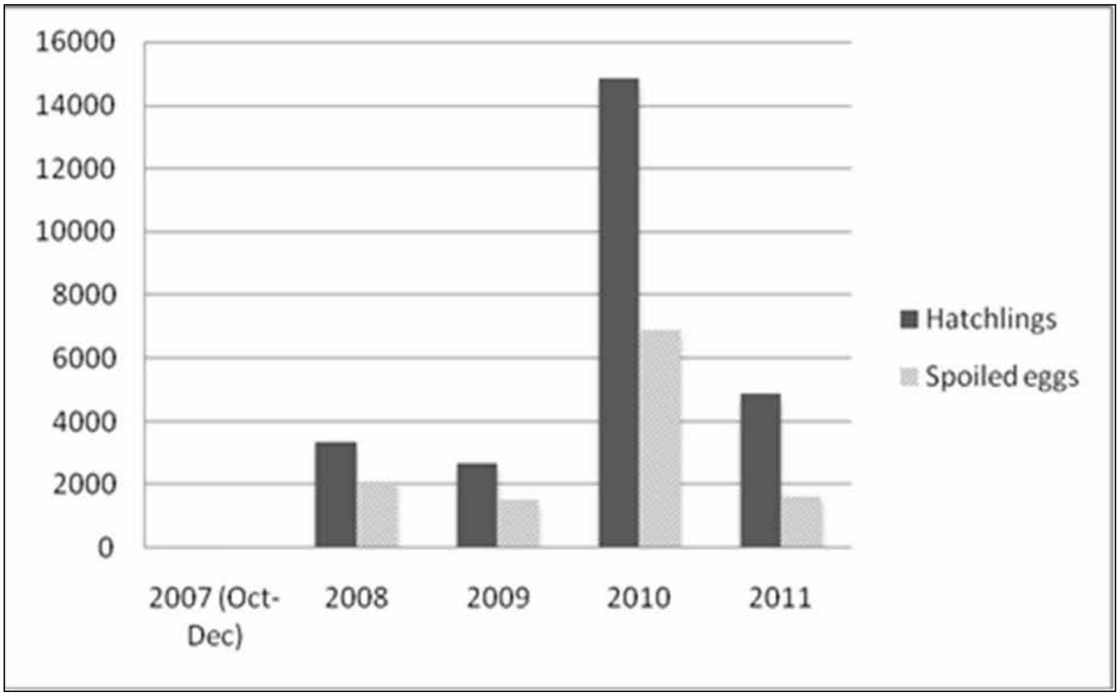

Figure 5. The number of hatchlings and unhatched eggs on nesting beaches of Daran Beach, 2007-2011

glue, and were strengthened by putting fiberglass cloth on top with resin solution. The natural movements of 12 of the turtles were successfully tracked, but three of the turtles appeared to have been picked by boats, since their movements were tracked as straight lines from Gwadar to Gulf States for a few days. The three transmitter signals stopped, when an effort to recover the lost/picked three transmitters was launched. Nevertheless, tracking of 12 of the turtles indicate a successful effort.

The results of this tracking portray daily movements of marine turtles between the Jiwani and Irani Coast. The most visited sites were Jiwani and Bandar Abbas, with turtles remaining for about 1.5 to 2 months in these areas. Two turtles, one tagged on Astola Island and one at Daran, travelled as far as UAE and appeared near Um-Alqueen (Figure 6 for the track from Daran to UAE). The westward movements of the turtles were successfully tracked to Iran, Iran, Qatar and UAE. No signals from transmitters were received from the Oman area, though. The eastward movements of two tagged turtles were tracked till east coast of India. The turtles traveled along the Makran Coast and reached the Sindh Coast in Karachi, from where these travelled to the east coast of India (Figure 7).

III. Community development initiatives

Daran is located off-road of Jiwani Town and has limited economic opportunities for the local community clustered in a 20 household hamlet. To motivate the community of Daran village and ensure their support for turtles conservation on Daran beach, a few initiatives were launched in consultation with them, including a community primary school for the children of the community, wind turbine and solar hybrid system to provide energy for lighting in the village and replace kerosene lamps, and build their skills in improved agriculture and livelihoods. This worked effectively and the community's support was ensured for conserving turtles.

DISCUSSION AND RECOMMENDATIONS

The Pakistan Wetlands Programme used enclosures made from wire mesh, which are subject to corrosion and thus last no longer. This approach was adopted for cost-effectiveness and to utilize local skills. There is a need to use material such as fiberglass that last longer, can be re-used several times and thus might have a lesser environmental footprint.

When the Pakistan Wetlands Programme ended in June 2012 the initiatives had to stop. Further funding is needed to ensure that the activities continue or the significant achievements made to date will be wasted. Although WWF Pakistan and the Balochistan Forest and Wildlife Department are making efforts to continue the conservation efforts at Daran, there is a need for resource mobilization to maintain the activities of the past few years.■

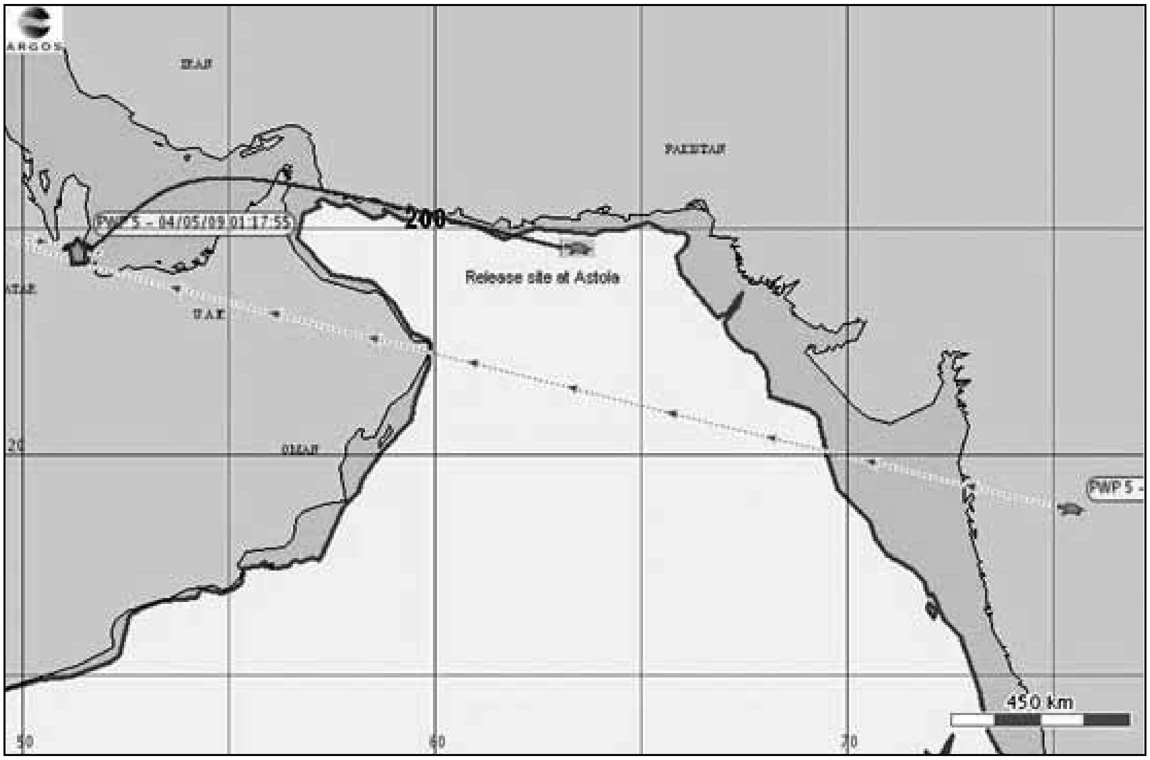

Figure 6. Post-nesting migrations of green turtles from Daran to UAE; the dotted arrowed line is between the test site of transmitter (Islamabad) and the active transmitter, while the solid red line shows the turtle movements.

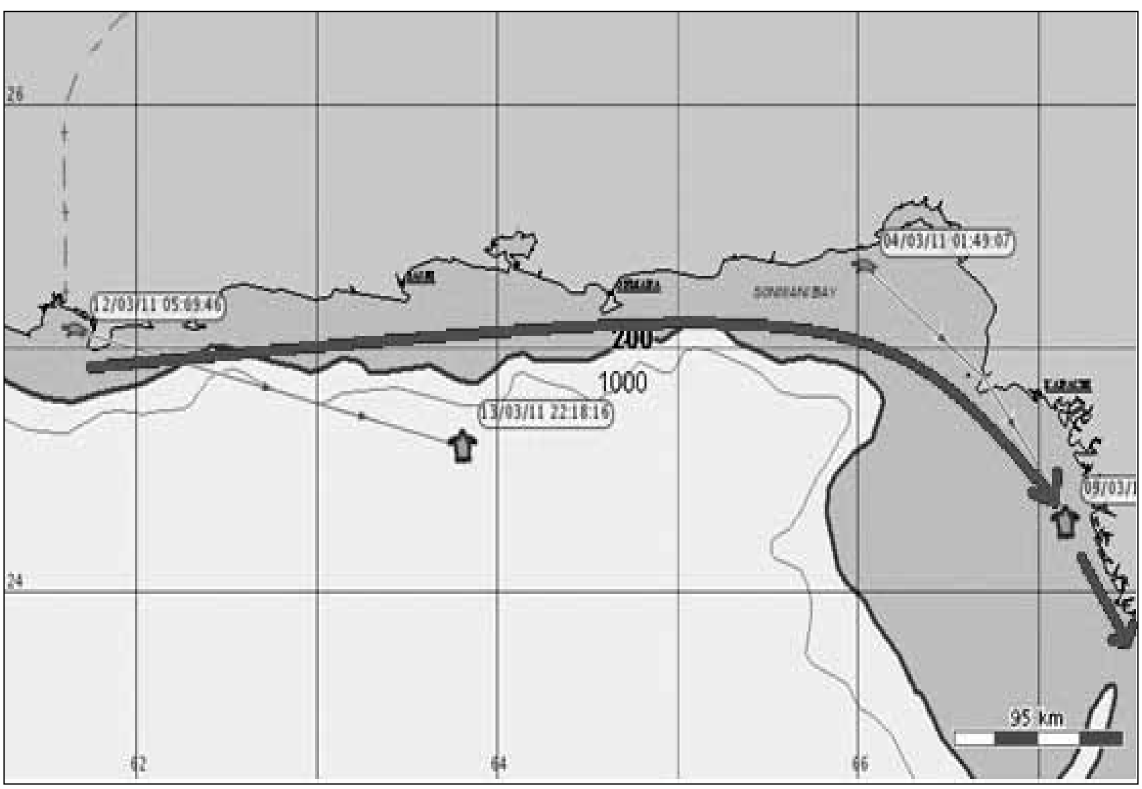

Figure 7. Eastward migration of two satellite tagged green turtles, from Daran to India.

PROJECT PROFILE

LOCAL OCEAN TRUST: WATAMU TURTLE WATCH SEA TURTLE CONSERVATION IN THE INDIAN OCEAN

RACHAEL OMAN

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The Project

Watamu, located 112km north of Mombasa, is internationally renowned for its outstanding beauty and recognised as a UNESCO world Biosphere Reserve. However, Kenya's Marine Protected Areas (MPA's) are under constant threat from over–development (often illegal), illegal fishing practices and weak law enforcement.

A group of Watamu residents involved with a local naturalist, Barbara Simpson, and her sea turtle nest patrols, consequently decided to increase their conservation efforts in the area. Their commitment and hard work resulted in the formation of Watamu Turtle Watch (WTW) in 1997. By 2002, in the face of extensive degradation of Kenya's coastline and reefs, WTW had clearly recognized the need for a more broad based marine conservation effort and Local Ocean Trust (LOT) was born. LOT is a marine conservation organization committed to promoting the sustainable use and management of Kenya's marine resources. The Trust undertakes general marine conservation work locally and nationally, promoting the protection of Kenya's MPAs. The name 'Local Ocean Trust' aims to encourage people to look after their own local ocean and promote the sustainable management of our marine resource.

In Kenya, there is mounting concern as the marine environment suffers increasingly from a range of anthropogenic threats, exacerbated by a lack of sustainable management, and a need for greater understanding of and respect for this precious resource. With the advent of mass tourism, increased coastal population, commercial fishing fleets, as well as the realization that our seas may hold rich petroleum fields and minerals, the pressure on Kenya's coastline and coastal waters has vastly increased. Around the world marine conservationists have pointed to the plight of sea turtles, a flagship species, as a key indicator of the fragile state of our oceans.

Turtle Nest Monitoring and Protection Programme

WTW have successfully run a nesting monitoring and protection programme for over 15 years, with the cooperation and support of the local community. Dedicated field staff carry out nightly beach patrols; in 2012, staff tagged and monitored more nesting females than any previous season. Nest monitoring has expanded over the years and now incorporates a number of beaches along the Kenyan coastline, including an extension of WTW on the South coast.

Watamu and the neighbouring beaches are predominantly *Chelonia mydas* nesting beaches but an increasing number of *Lepidochelys olivacea* area being encountered. Nesting females return every 3-5 years and lay on average 4 clutches of eggs per season. Since the inception of the nesting programme over 550 nests have been monitored and protected *in situ*, with an average hatchling success rate of over 70%. This percentage also includes nests that have been poached, washed away by high tides as well as non-viable eggs. In addition to natural pressures, nesting populations in Kenya face a range of serious anthropogenic threats, including extensive poaching for meat, carapaces and oil. Nesting females and hatchlings face additional significant pressures including illegal beach structures, sea walls, sun beds and umbrellas as well as bright artificial lighting from hotels and homes which cause disorientation.

By-catch Net Release Programme

By 1998, WTW had gained an understanding of the extent of sea turtle useby fishermen in the Watamu area and a trial 'compensatory net release programme' was implemented for turtles incidentally caught by local artisanal fishers.

Figure 1. Green turtle undergoing rehabilitation, being taken for a sea bath
Photo credit: Rachael Oman

The programme encourages artisanal fishermen to release, rather than slaughter their accidental sea turtle by-catch and has grown steadily since its inception in 1998, with each year seeing an increase in the number of participating fishermen as well as the number of turtles being released. A small compensatory sum of approx. $3.50 USD (dependent on turtle size) is offered to the fishermen for their time and effort. The programme works alongside LOT's education and community awareness programmes, in order to maintain cooperation with local fishing communities and its success reflects progress towards a change in local attitudes towards conservation.

The LOT: WTW By-catch net release programme is believed to be the longest running programme of its kind worldwide. This programme has highlighted the Mida Creek Reserve and Watamu MPA as nationally important foraging grounds for juvenile green and hawksbill turtles, which have been found to reside there all year round.

Rehabilitation Centre

In response to a number of sick and injured sea turtles being reported to LOT: WTW, a rehabilitation facility was built in 2003. This facility has expanded over the years, to include 9 tanks and a treatment clinic. The project liaises with a local vet who visits the centre on a weekly basis and assesses any newly admitted turtles. A variety of conditions are treated, including fish hook and spear-gun injuries, boating accidents, flipper amputations, exhaustion, infection and disease. The number of turtles admitted to the centre has been steadily rising each year. Most animals come through the LOT: WTW by-catch net release programme that runs all year round, but the centre also receives turtles from adjacent areas of the East Africa coast. The centre has been home to over 170 turtles since it began and over 70% of these turtles, that would probably have died without medical assistance or care, have been successfully released.

Data Collection and Research

A database has been set up to manage 15 years' of field research data. Allowing project staff to develop a much improved understanding of Kenya's turtles, including population estimates, population feeding patterns, and prime catch areas. A hatching model, using temperature, weather patterns and 14 years of previous data, has also been developed to more accurately predict emergences. This model has been invaluable and has enabled staff to successfully predict and attend 98% of "nest emergences" during the last season. The database has also made it possible to highlight 'hot spots'where turtles with fibropapillomatosis have been encountered. LOT: WTW also collect data during monthly beach surveys to track changes in topography, and indicate areas ideal for sea turtle nesting and show areas that are poor nesting sites.

Community Outreach and Awareness Programme

LOT: WTW are currently engaged with 13 community groups, raising awareness about conservation issues as well as supportingcapacity building and training. Staff work alongside the community to conduct beach clean-ups and mangrove restoration. The organisations motto 'love your local ocean' is used to emphasize the importance of local people taking ownership of their natural environment in order to preserve for the future.

Education Programme

Twenty-six local schools are currently taking part in the education programme which offers children the opportunity to learn more about sea turtle conservation, coral reef ecosystems and mangrove protection. The LOT team teach children about the importance and benefits of protecting their local marine environments and all its inhabitants. The project also welcomes international schools and universities and receives local and international university interns on a regular basis. In addition, the Marine Scout programme is designed to encourage young conservationists and teaches young people basic scientific surveying and species identification skills, as well as allowing them to assist in by-catch releases and data collection.
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RESEARCH SUMMARY

FROM MINI-TRANSMITTERS TO MOLECULAR MAPS: A NEW FRONTIER IN THE STUDY OF AT-SEA MOVEMENTS BY SEA TURTLES

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Every so often there comes a time when scientific knowledge in a particular field of sea turtle biology and conservation sees rapid expansion in a short period. Now, after decades of infrequent study of the lives of sea turtles on the high seas, we've seen a blossom of papers over the last few years that are enlightening our understanding of the pelagic ecology of sea turtles. Indeed, this dearth of knowledge is rooted in the logistical hurdles and inaccessibility of turtles in areas far from shore, but change is happening rapidly thanks to the development of research techniques that seemed far-fetched only a few years ago. In the passages below, I describe three areas of interest that I believe are in the fast lane of research and development. First, in one of the coolest advances in the history of satellite telemetry, we are now able to track the movements of neonate turtles thanks to the smallest-ever satellite tags and innovation in tag attachment methods. Here I describe the work of Kate Mansfield and colleagues in this endeavor. Second, in what is truly a renaissance for stable isotope research of sea turtles, I discuss how researchers are tracking the movements and prior whereabouts of turtles based on only a small piece of skin or scute. And finally, in a superb example of blending to high-technologies, I describe how researchers are linking stable isotope analysis with skeletochronology to determine the duration of an individual's oceanic juvenile stage, otherwise known as the Lost Years. Together, these avenues of research exemplify innovation and rapid technological progress, and while there is still much to be done, they are helping unravel some of the most contemplated mysteries in sea turtle science.

Solar tags and satellite tracking of neonate turtles

With the increasing application of satellite telemetry, more attention than ever is being paid to the hydrodynamics and energetic impacts of transmitter attachment to turtles (Jones *et al.*, 2011). Telemetry techniques have evolved much in the last 20 years, and one of the greatest advances for tracking turtles is the development of the direct attachment technique for equipping leatherbacks with satellite transmitters (Fossette *et al.*, 2007). But on an entirely new telemetric front, owing to the pioneering efforts by a team of researchers in the US, we are, for the first time able to monitor the movements of post-hatchling / neonate turtles thanks to the progressive miniaturization of satellite tags coupled with a nifty new method for attaching tags to these fast-growing critters. Of course, for years the efforts of Blair Witherington (e.g. Witherington, 2002) and others had pinpointed the whereabouts of neonate sea turtles living among the flotsam and jetsam that aggregates in frontal areas and convergence zones many km from shore. However, not much was known about how these turtles moved in the open ocean. In the mid 2000s, thanks to efforts of George Balazs, Jeffrey Polovina and colleagues, we learned about the movements of headstarted, small juvenile loggerhead turtles *(Caretta caretta)* in the North Pacific (e.g. Polovina *et al.*, 2006). However, still elusive was the capability to tag even smaller neonate turtles. After years of yearning for small transmitters, there has been a new technique to come along with transmitters so small that they fit on hatchling and post-hatchling turtles. In what is to my knowledge the satellite telemetry of post-hatchling turtles, Kate Mansfield and colleagues implemented the use of small-scale solar-powered satellite tags and developed an exquisite attachment method that allows for tiny turtles' carapaces to grow while still having the tag attached (Mansfield *et al.*, 2012). Owing to these efforts, we are finally able to pinpoint the movements of these small critters in their oceanic developmental grounds, and the first ever insights in this respect are coming from neonate loggerheads tracked in the western North Atlantic (Mansfield and Putman, in Press). In this study, the research team attached solar tags to 17 neonate loggerheads ranging from 11 to 18 cm and tracked their movements for up to 219 days as they moved north along the US southeast coast, and then out into the pelagic realm of the western North Atlantic. Amazingly, one of the neonates was tracked all the way to waters near the Azores, which for the size of the turtle and novelty of the attachment method is a triumph for sea turtle research.

Stable isotope tracking of sea turtles

In addition to the value of stable isotope analysis (SIA) for determining the trophic status and diet of sea turtles, this technique can decipher the key foraging habitats used by sea turtles. While not as precise as satellite telemetry, SIA is much lower in cost, and a viable tool for tracking animal movements because the isotopic composition of consumer tissues integrates isoscape information from foraging environments, such that when a sea turtle moves among spatially discrete food webs that are isotopically distinct (i.e. isoscapes), stable isotope values of its tissues can provide information about its previous location. There have been several studies that have shed light on marine isoscapes, and this is an area of rapid advancement that for now still depends on blending the isotope technique with satellite telemetry, so that turtles' isotopic signatures can be ocean-truthed for their whereabouts. A study by McClellan *et al.* (2010) of loggerhead turtles in the eastern United States was the first study, to my knowledge, that used satellite telemetry to establish the spatial patterns of marine isoscapes; in their case, showing an isotopic dichotomy between juvenile loggerhead sea turtles that foraged coastally versus those that foraged in offshore waters. Zbinden *et al.* (2011) similarly showed a migratory dichotomy and associated phenotypic variation in Mediterranean loggerhead turtles. However, it wasn't until even more recently that researchers have started to decipher the isotope spatial patterns in the oceans in hopes of tracking animal movements based exclusively on the isotope technique (i.e no telemetry). And in some of the first steps to establish an 'isotope map' of the ocean, two studies of loggerheads in the western North Atlantic (Ceriani *et al*., 2012; Pajuelo *et al.,* 2012) linked satellite telemetry with isotope analysis to help elaborate the isotopic spatial patterns in the western Atlantic Ocean, finding that variation in δ13C and δ15N in post-nesting Florida loggerheads can be explained by differences in food-web baseline isotopic signatures that vary spatially. An effort by Seminoff *et al.* (2012) in the Pacific has provided similar insights for Indonesian leatherbacks that used eastern and western Pacific foraging areas. Indeed, there is much more we need to learn to fill out the isoscape map based on sea turtle migrations, but the foundation is being laid for stable isotopes to more richly augment spatial movement information derived from the much-more costly telemetry technique.

Using stable isotopes and skeletochronology to determine the Lost Years duration

Elucidating the duration of time turtles spend in distinct habitats – particularly in the remote pelagic stretches of our World's oceans – is critical to successful conservation, as threats and protection strategies vary greatly between coastal and open ocean habitats. While Archie Carr was the first to speculate on the multi-year duration of small sea turtles' oceanic phase (a.k.a. the Lost Years), there has been a growing suspicion that this phase may be better termed the 'Lost Decade'. But to get at this question required some means to age turtles, and this did not come along until George Zug perfected the skeletochronolgical aging technique (e.g. Zug *et al.*, 2001). With this technique firmly established in the repertoire of next-generation skeletochonologists, such as Melissa Snover and Larisa Avens, the possibilities seem endless. As mentioned in the previous passage, stable isotope values vary spatial in many ocean regions, and that fact that sea turtle humerus bones deposit annual growth rings with nutrients derived from their foraging areas means that each growth ring should have the isotopic profile of the foraging area(s) that was occupied during that year deposited within it. Thus, by studying the isotopes in these growth rings, and knowing what year of life each ring corresponds to, researchers have a chronological annual record of where that turtle resided prior to its death. This is possible because nearshore and offshore regions often have isotope 'signatures' that are distinct from one another. The first efforts linking skeletochronology and SIA were conducted by Melissa Snover, and she was able to discern habitat shifts in loggerhead turtles that had stranded along the U.S. east coast (Snover *et al*., 2010). Since then, a series of new studies have been conducted – or are being conducted – by the likes of Larisa Avens, Bradley MacDonald, and Cali Turner-Tomaszewicz. These studies have expanded from the western North Atlantic to include areas in the Pacific, and I expect that soon we'll have insights on oceanic juvenile stage durations for multiple loggerhead and green turtle *(Chelonia mydas)* populations from around the world. Archie Carr would have been proud.

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RESOURCES OF INTEREST

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